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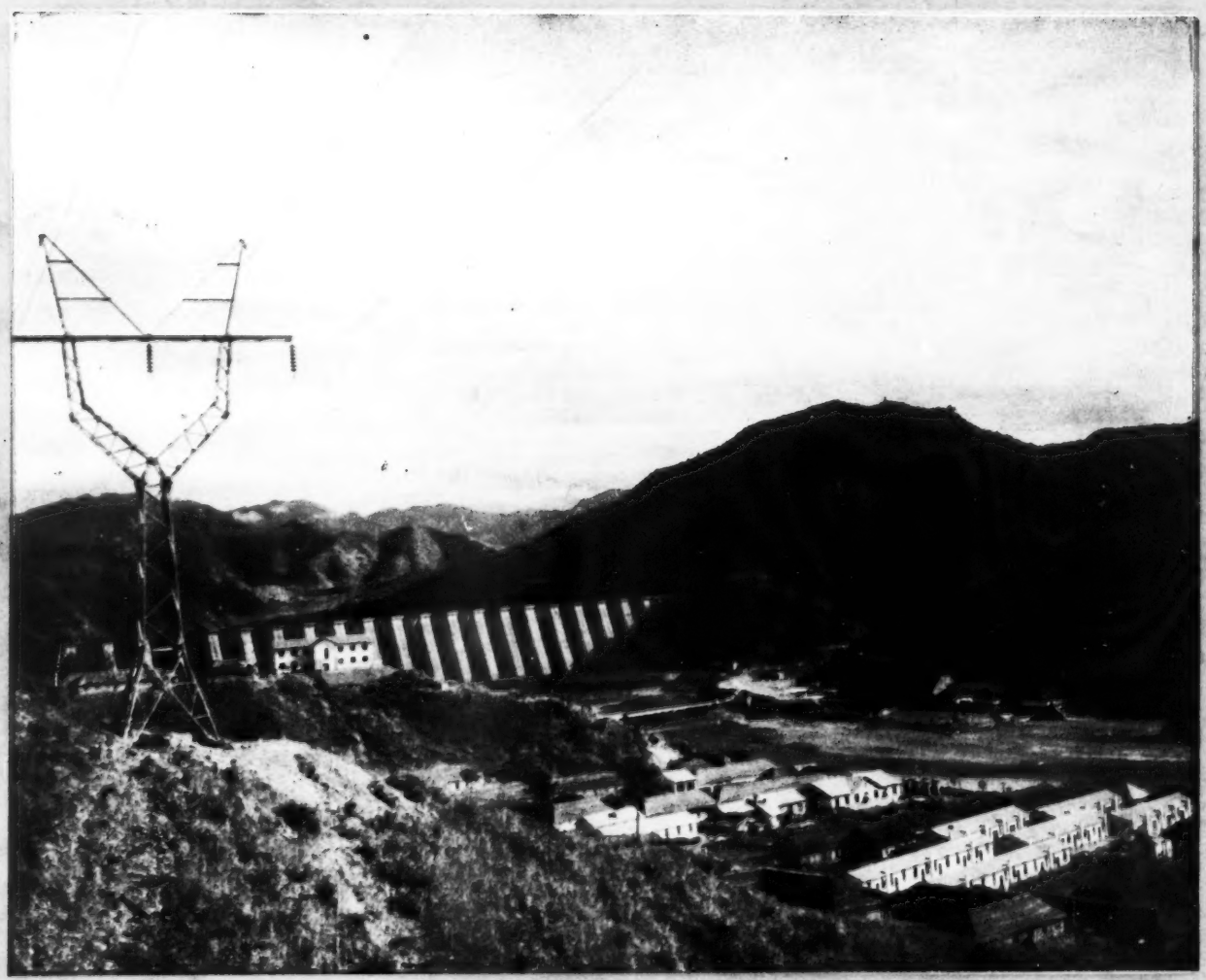

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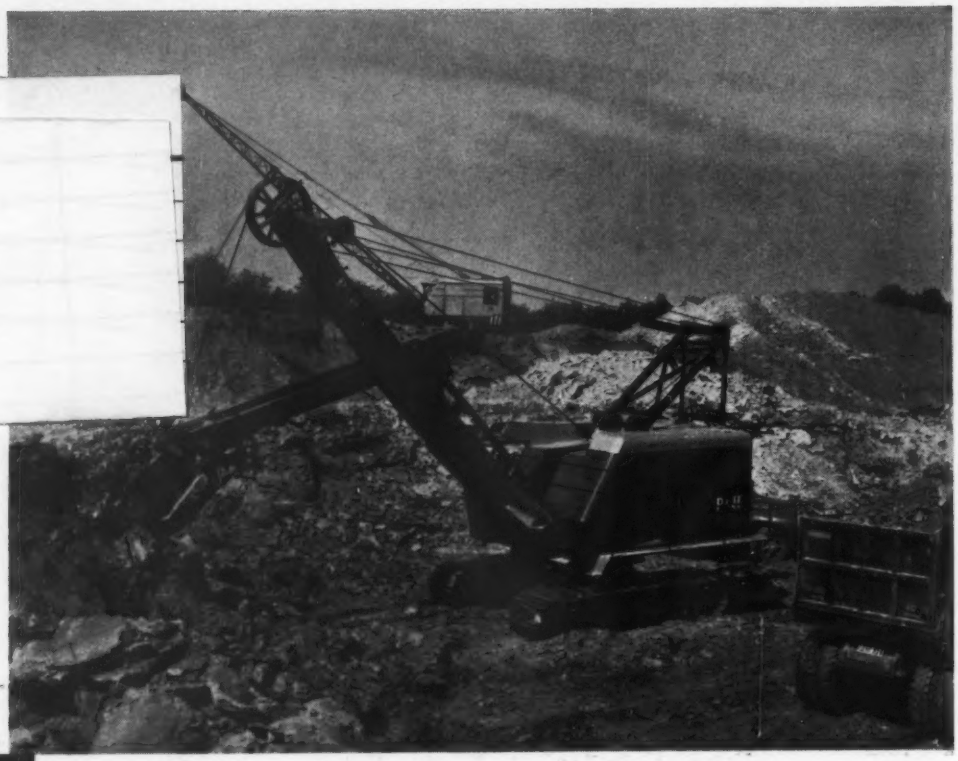

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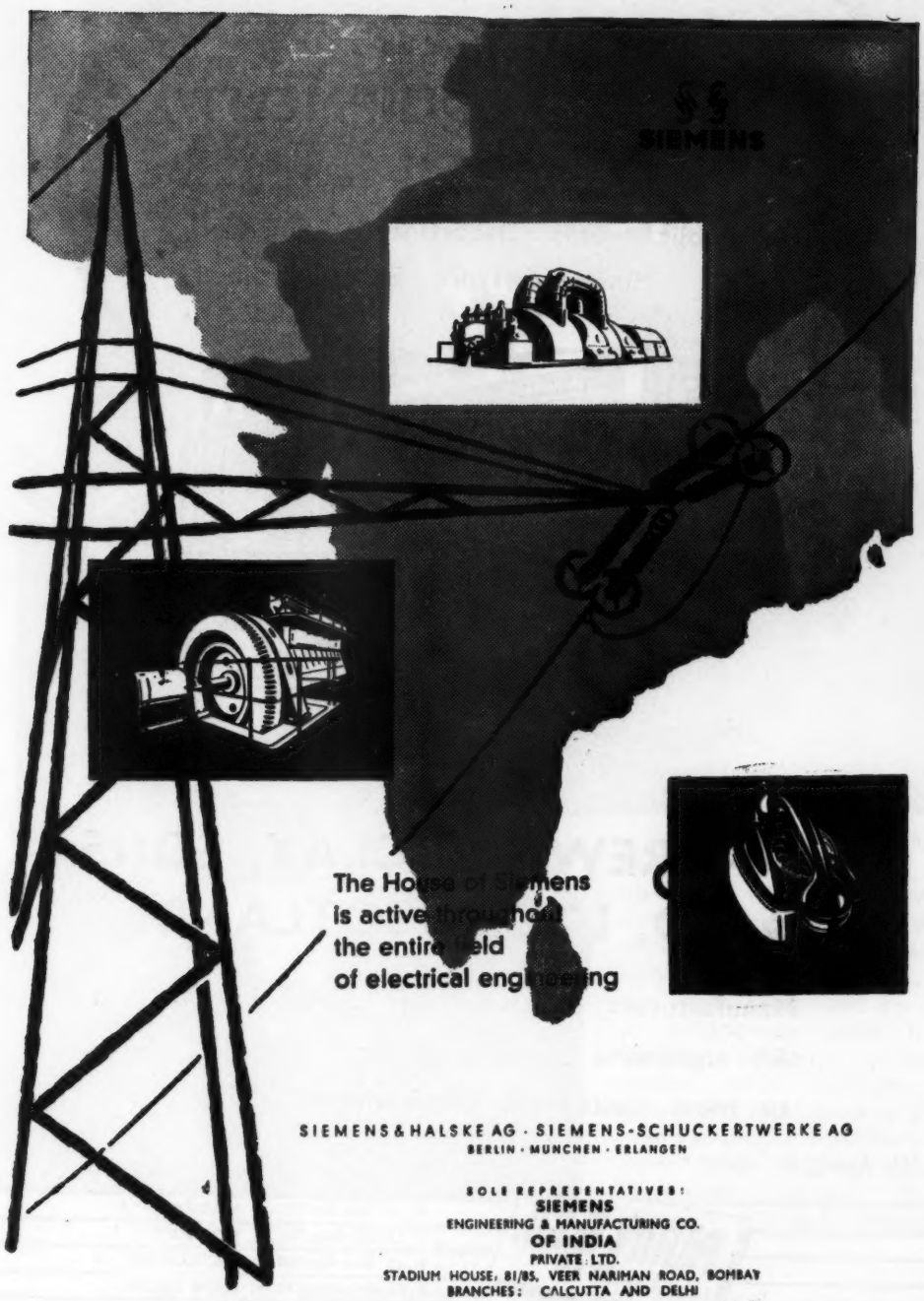

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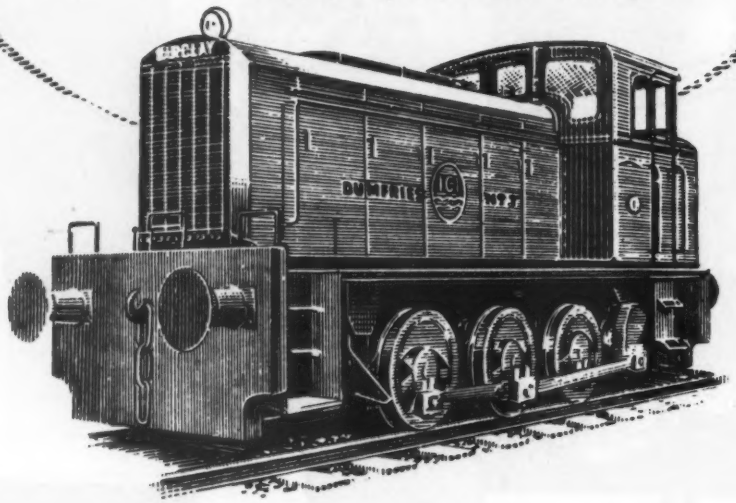

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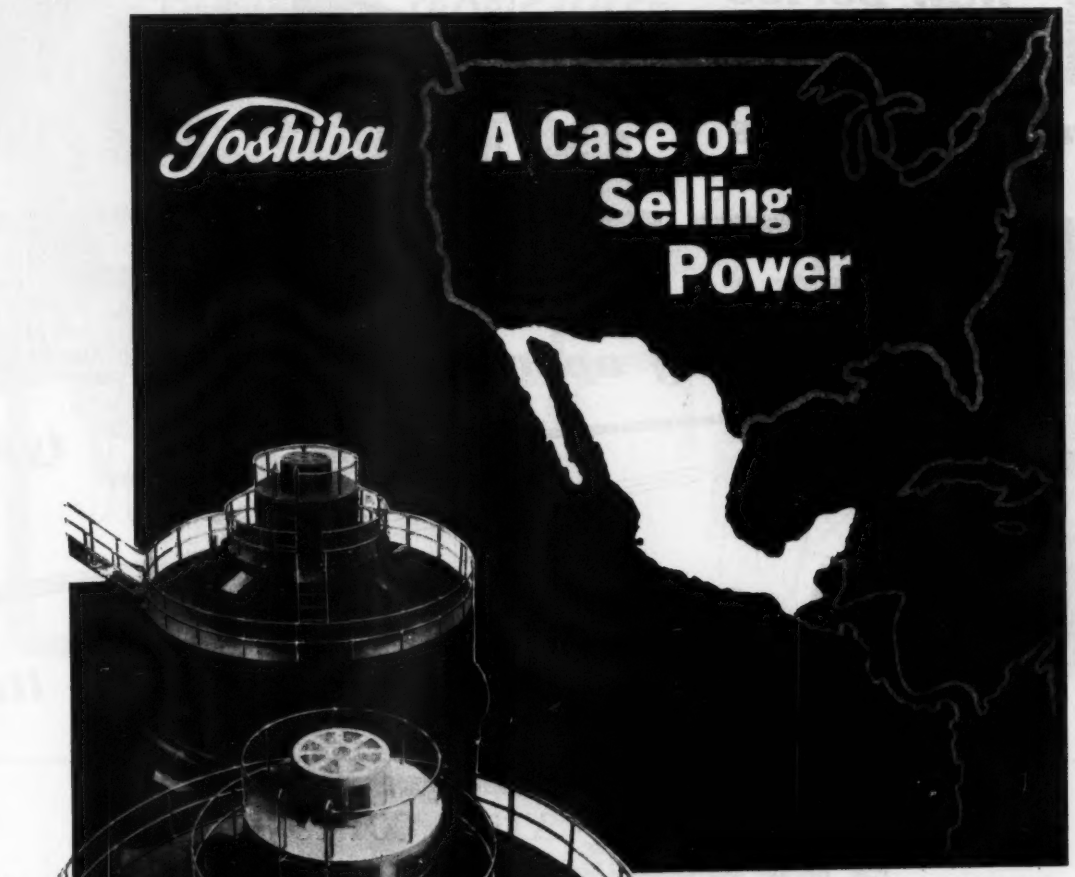

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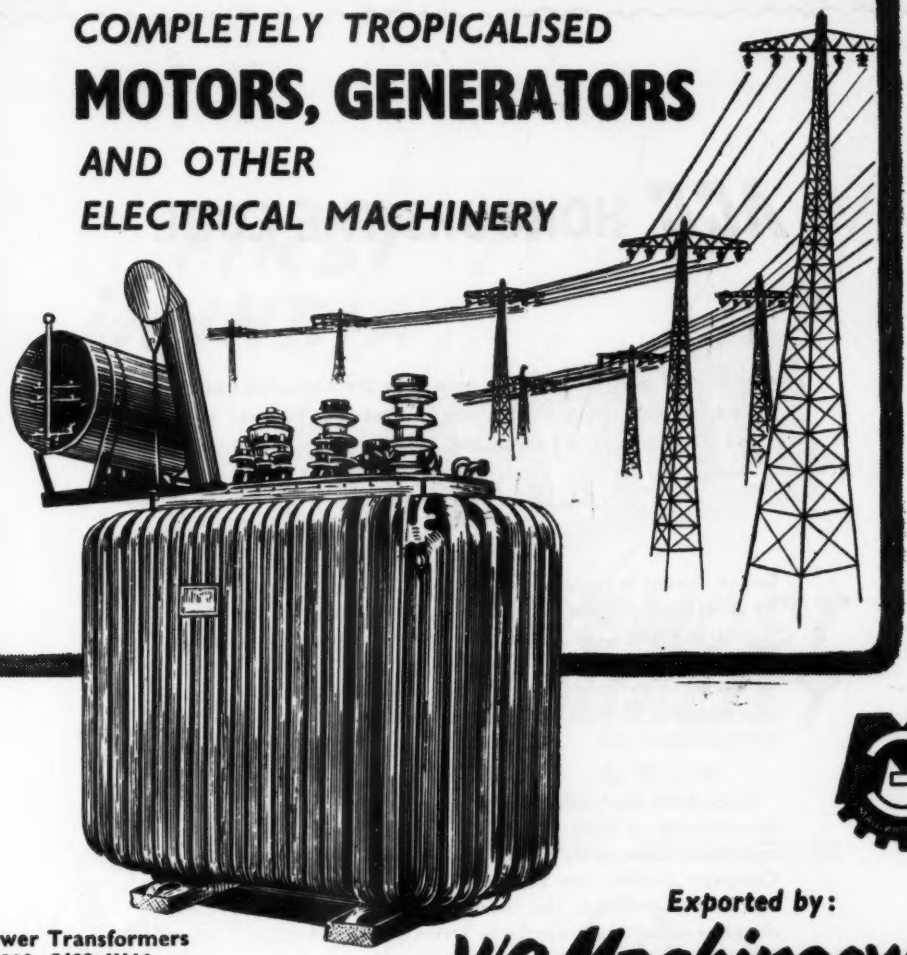

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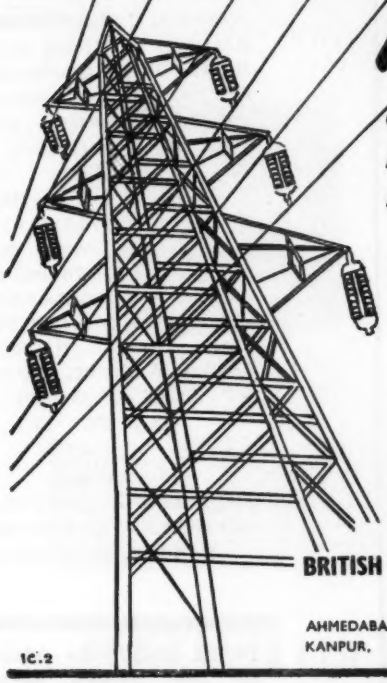

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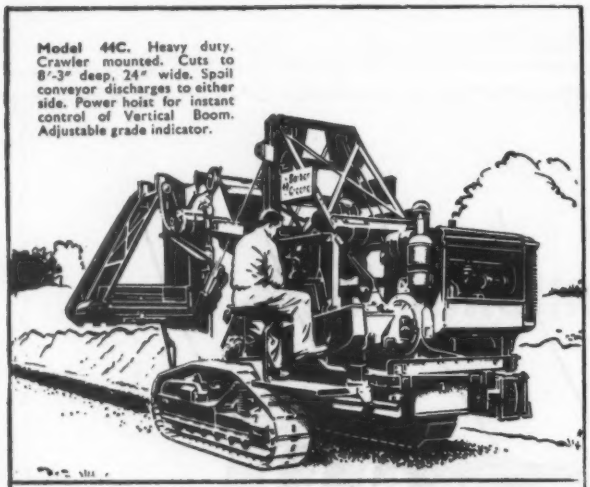

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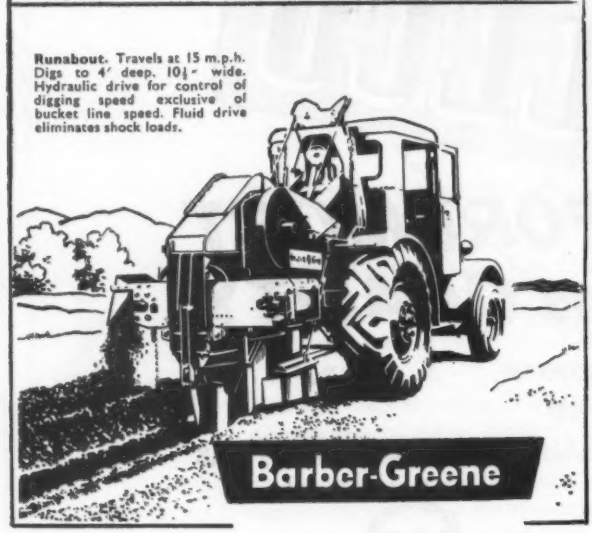

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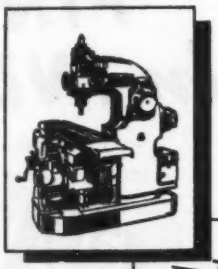

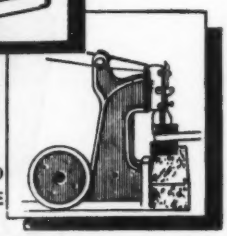

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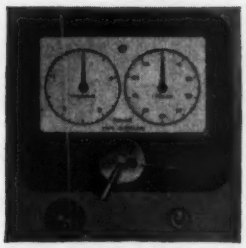

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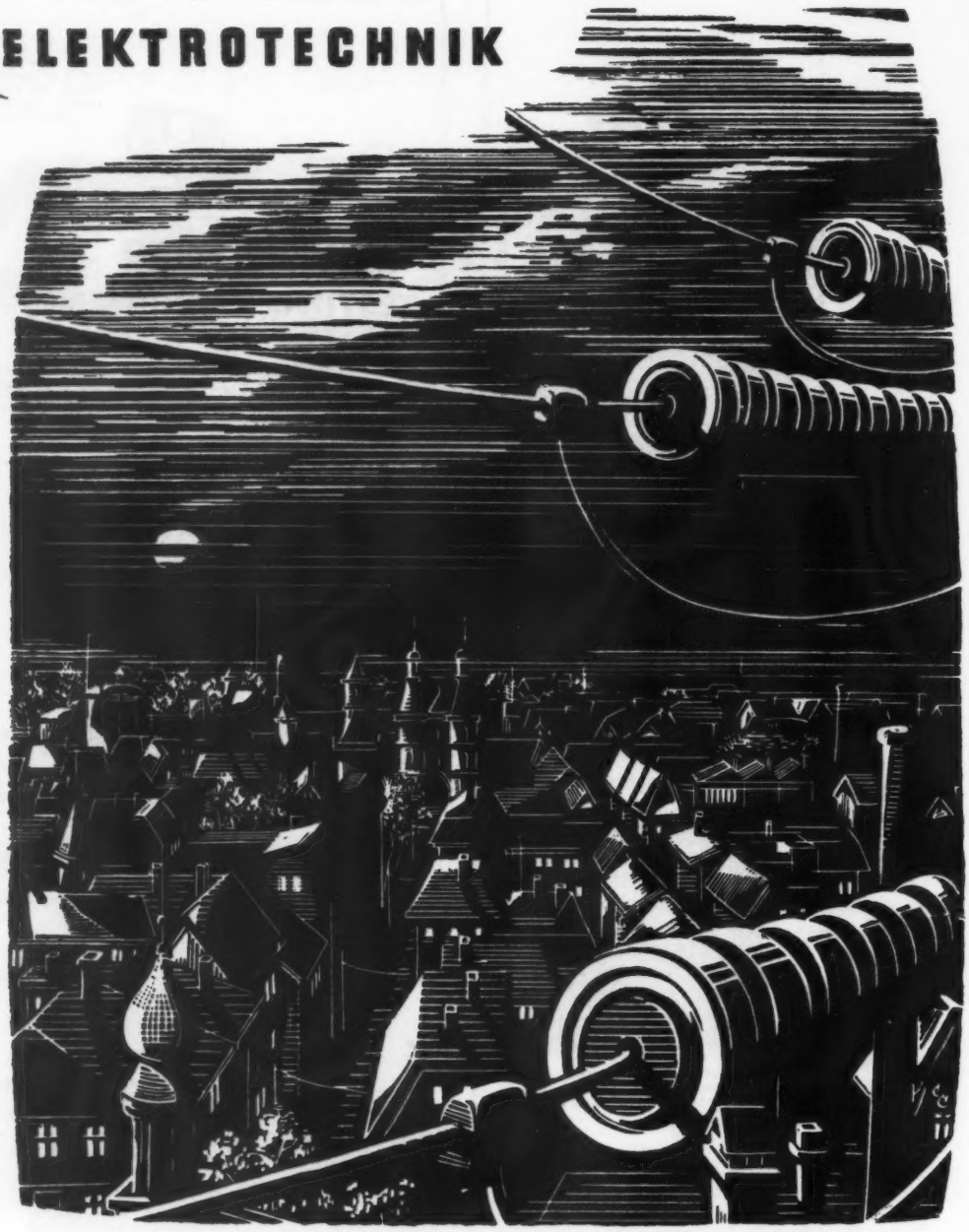

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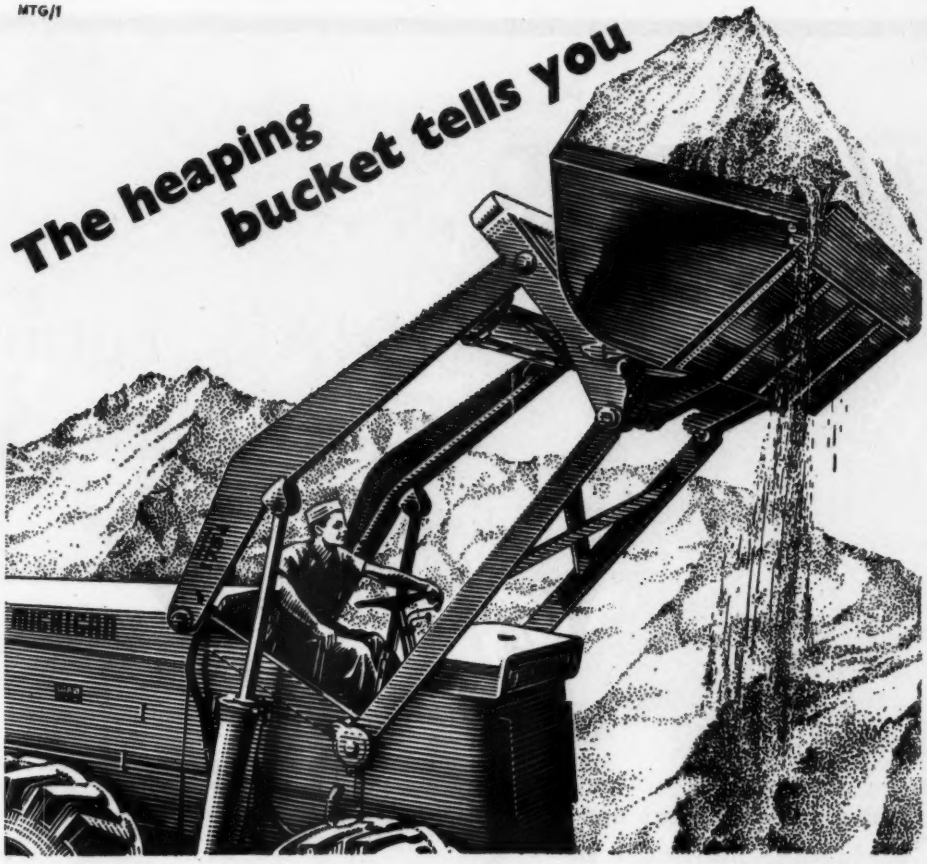

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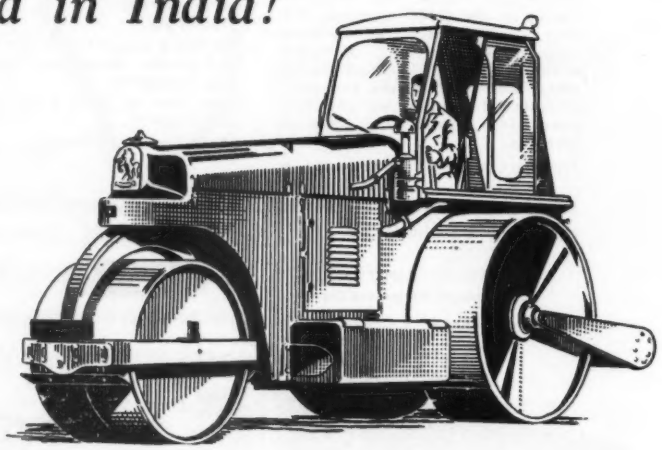

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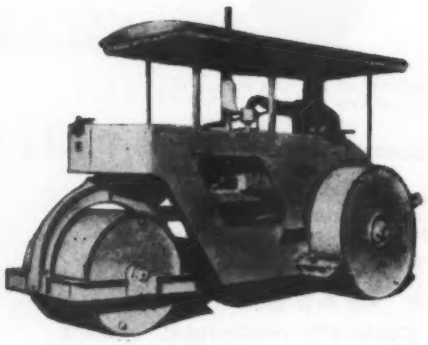

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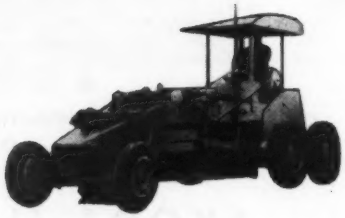

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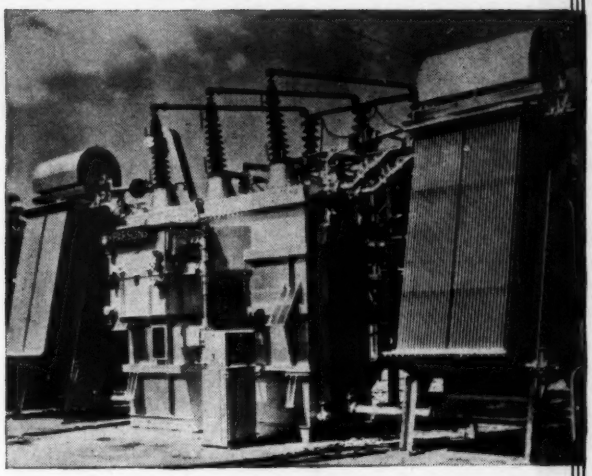

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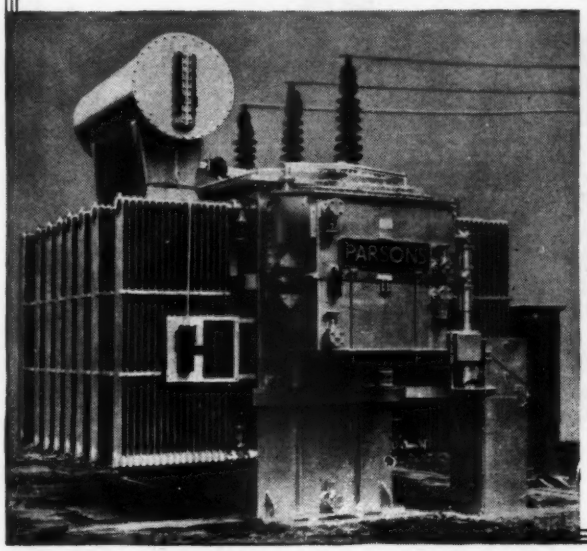

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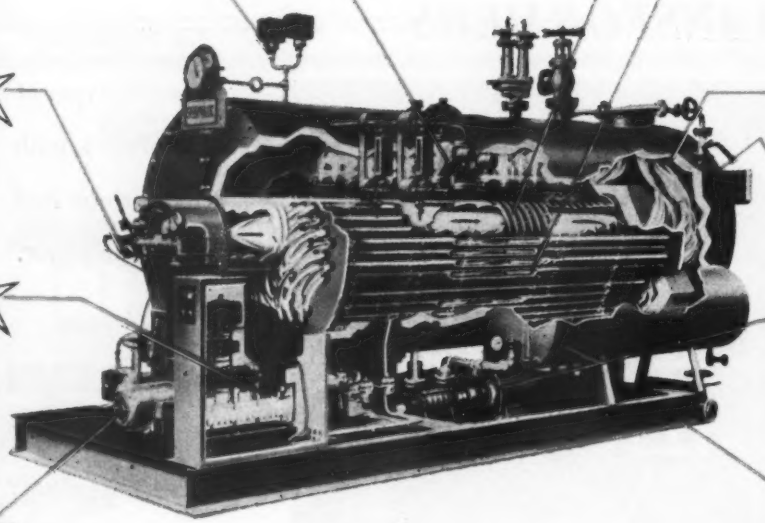

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Geologic conditions affecting Design and Construction of Pressure Conduits and Power House underground *by* B. S. Sathya Narayanswami, Dept. of Geology, National Institute of Engineering, Mysore; A Statistical analysis of Evaporation Loss in Damodar Valley *by* Dr. K. C. Majumdar, M.Sc. D.Phil, Regional Meteorological Centre, Calcutta; Drainage study of lower Damodar *by* Satyakam Sen, M.A.

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China's Power Industry: Yesterday and Today

By CHEN CHI-YUAN
Director, Designing Department, Ministry of Electric Power Industry

China is a country very rich in power resources, but before the founding of the People's Republic her power industry was insufficiently developed and backward in technique due to her semi-colonial and semi-feudal political and economic system. In 1949, the year of liberation, the total generation in the whole country was only 4.3 billion kW-h, with an average of only 7 kW-h per capita, and the total installed capacity (above 500 kW units) amounted to only 1,850 mW. The power plants were scattered and isolated. Plants less than 3,000 kW. in capacity comprised more than 60% of the total. As a result of small plant capacity, low steam pressure and temperature and inefficient management, coal consumption exceeded 0.9 kg/kW-h (standard coal) and house service and line loss amounted to almost one-third of the total generation.

Rehabilitation and Restoration

From 1950 to 1952 the rehabilitation of China's national economy proceeded rapidly. During this period the total industrial production value was increased by 1⅓ times that of 1949. To ensure adequate power supply for the rehabilitation of industries, time did not permit the construction of new plants. But it was perceived that renovation and rehabilitation of existing equipment could meet the immediate requirement. So the main task of the power industry was directed along these lines.

Generators being made in the state-owned Shanghai Power Equipment Plant for the power plant in Lhasa, Tibet, built recently.

There were four tasks during this period : firstly, to carry out major overhaul of defective machines resulting from long and inappropriate operation in order to boost up to their nameplate rating ; secondly, to interconnect the isolated power networks instituting central load dispatching and control, so as to provide mutual relief ; thirdly, to economise rationally by reduction of operational losses and scheduling of load ; and fourthly, to save fuel.

By adopting these measures, about 200,000 kW of generating capacity had been restored, and annual utilization hours were raised from 2,300 in 1949 to 3,700 in 1952. So, with an increase of barely 6% in capacity, the total generation had been increased by 68%. Fuel consumption was also greatly reduced. In the technical and economical indices between 1949 and 1952 the following improvements are shown :

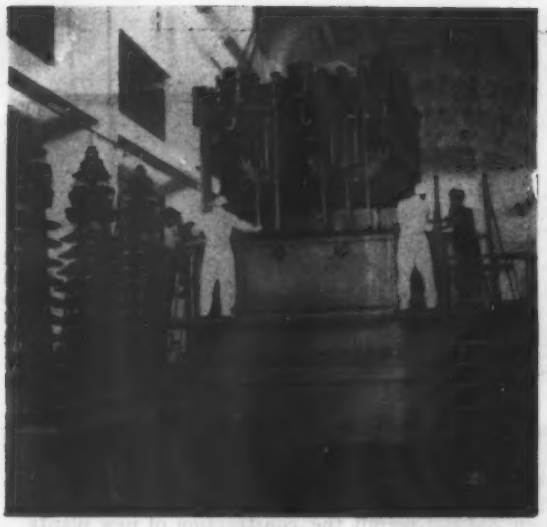
1. Coal consumption reduced from 0.925 kg/kW-h to 0.659 kg/kW-h.
2. House service reduced from 7.73% to 5.76%.
3. Line loss reduced from 24.84% to 12.56%.

The above accounted for a saving of 2 million tons of coal and 10 billion kW-h annually.

By the end of 1952, which marked the completion of the rehabilitation of the national economy, the total annual generation was brought to 7.26 billion kW-h.

The First Five Year Plan

China's First Five-Year Plan, which started in 1953, specifices that within five years the total industrial production value should be doubled. In order to meet the requirements in industrial development,especially in new industrial districts, the power industry has had to be vigorously developed through the construction of new power plants and the renovation of existing ones. By 1957 the projected annual generation



A transformer of 110,000 volts and 7,500 k.V.A. being made for the first time in the state-owned Shanghai Power Equipment Plant. It will be used by one of the hydro-power stations on the Huai River.

will be 15.9 billion kW-h with an increase in generating capacity of 2 million kW. The First Five-Year Plan specifies principally the construction of steam power plants, including extraction plants. At the same time, hydro-electric power plants are to be constructed utilizing all available data of China's resources. The surveying of water power resources is to be carried out with concerted effort to pave the way for the future.

There are 107 principal construction projects for the power industry within these five years, 92 of which being power stations, the other 15 transmission and its associated transformation projects. Of the 92 power stations, 69 are central stations, 22 regional stations and the rest are railway mobile power plants, with a total projected capacity of 3.76 million kW. These, together with other construction projects which are to be completed within these five years will commission an added generating capacity of 2.05 million kW. equivalent to the total generating capacity in the whole country in 1952.

Of the 92 power stations, 76 are steam electric stations, including 19 extraction stations. For all the new power stations the steam pressure selected is over 40 kg cm² abs,. For 17 of them, over 100 kg/cm² abs. covering 47% of the total projected capacity. The remaining 16 are hydroelectric stations.

Hydro-Plants

Within these five years, the unified planning for a multi-purpose utilization of the water power resources of the Yellow River will be completed and its first stage engineering project will commence in the construction of Sanmen Gorge hydro-electric station with an ultimate capacity of 1,000 mW.

The largest hydro-electric power plant now in commission in China is the Fengman hydro-plant. As a part of the First Five-Year Plan, renovation of the plant according to modern standards has been carried out with the assistance rendered by the USSR. The dam of this hydro-power project which was left unfinished by the Japanese occupationist and found to be leaking badly at the time of liberation has been rebuilt and strengthened. All the machines installed are equipped with automatic control. After the completion of this renovation in 1957, the generating capacity of this plant will be 567 mW

There will be a considerable increase in the generating capacity of hydro-plants within the five years. The percentage of the generating capacity of hydro-plants as compared with the total in China will be raised from the 9.3% of 1952 to 17.1% in 1957.

Within these five years preparation will be made for the utilization of water power resources along the Yangtze River and its principal tributaries and the rivers in the Lhasa area.

Transmission Networks and Manufacturing Industrie

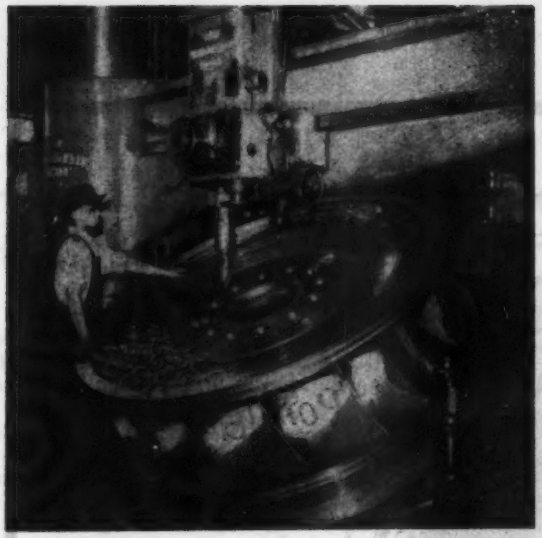
The First Five-Year Plan prescribes principally the installation of regional power stations—hydro-plants or extraction plants—of comparatively large capacity to be inter-connected throughout the country via 10 high voltage transmission networks of various capacities.

The supply of equipment and techincal assistance for the construction of those power plants in the First Five Year Plan are mainly rendered by the USSR and the People's Democracies. The rest are of Chinese make, or supplied by Western and Northern European countries.

Improvement in operation indices as specified in the the First Five Year Plan are :

1. Coal consumption to be lowered to 590 gr-kWh (standard coal)
2. Line loss to be lowered to 10.73%.
3. Annual utilization hours of equipment to be increased to 4550.

Interior of the Kirin extraction plant in Northeast China, which is equipped with high pressure, high temperature steam boilers and turbo-sets of large capacity.



The wheel of the 12,000-kW hydro-electric generator being made in the Harbin Power Equipment Plant in Northeast China.

China must develop her own manufacturing industries. The First Five year Plan specifies the construction of boiler, turbine and generator factories; motor, cable measuring instrument and carbon brush manufacturing factories; and the renovation of motor, switchgear and transformer factories. These factories are to be successively completed from 1955-1961.

After completion of these factories, there will be a total annual manufacturing capacity of generating equipment of 800,000 kW. according to their projected capacity, including steam electric generating equipment of 12,000, 25,000 up to 50,000 kW units and hydro-generating equipment of 75,000 up to 150,000 kW. units.

Targets Overfulfilled

The power industry has fulfilled and over-fulfilled its assigned quota in the first three years of the First Five Year Plan. During the three years (1953-1955) an increase in equipment capacity of over one million kW were materialized. It is expected that in 1956, an additional 500,000 kW will be installed. The first extraction plant of 101 kg/cm² abs. 510°C was put into service ahead of schedule in 1955. A 366 km. 220 kV transmission line was put into service in 1954. also ahead of schedule. Power plants equipped with 10,000 kW. hydro-sets and 6,000 kW turbo-sets, all of Chinese make, are now in commission. A Chinese designed, tele-controlled hydro-plant of 6,000 kW capacity in the vicinity of Peking will be commissioned this year.

By the end of 1956, it is expected that the production, technical and economical indices will reach the level set forth for the year 1957. It is possible that the 1957 power generation will reach 17 billion kW-h, exceeding the level set forth in the First Five Year by 1.1 billion kW-h.

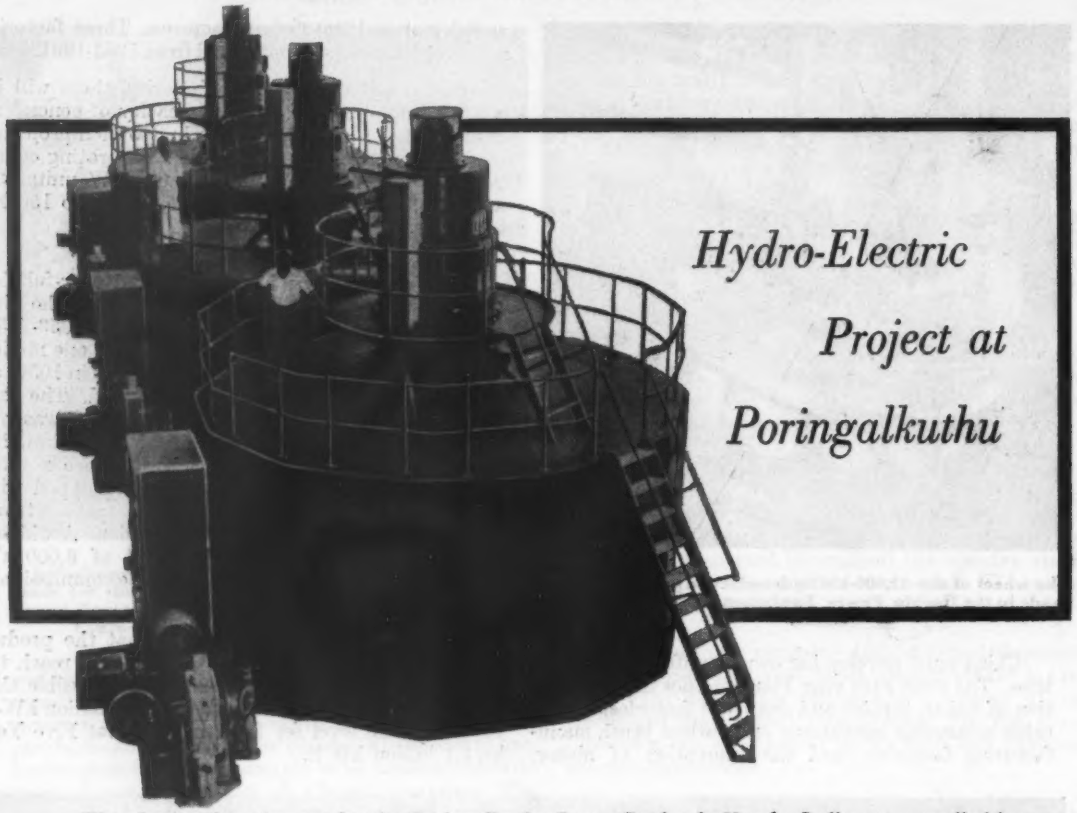
The Fengman Hydro-electric Station, China's largest, now being renovated to increase its capacity.

Radioactive Ratemeter

A battery-operated instrument designed for geological surveying, maping, and prospecting for radioactive ores and for the examination of mine workings has been developed in conjunction with Britain's Atomic Energy Research Establishment. When the instrument is used in conjunction with the associated beta probe unit, assay work can be carried out in the field. The equipment, by Ericsson Telephones Ltd., of Beeston, Nottingham is known as the "1368" Field Ratemeter.

The instrument is a particle counter which incorporates a junction-type transistor and four Geiger-Muller tubes. The counter rate is shown on a 50-microampere indicating-meter calibrated in mill-Rontgens per hr. Five ranges available in the instrument cover count rates of O to 25 milli-Rontgens per hr. An accuracy of either 10 per cent. or 2 per cent. can be chosen by operating a selector switch, and the speed of response of the instrument depends on the accuracy chosen.

The power supplies are all derived from three 1.5V torch cells, and a stabilizer ensures that the instrument is not affected by changes in battery voltage between 3V and 4.5V.



The plant and equipment for the Poringalkuthu Power Station in Kerala, India, was supplied by The English Electric Company. The equipment included

● Three Vertical Shaft 8,000 kw, 11,000V. 600 RPM Alternators complete with main and pilot exciters. ● Three 10 MVA—11 kV./66-110 kV. step-up Generator Transformers, OFW cooled. ● Three 500 kVA. 11 kV./440 Vs. ON cooled Unit transformers and ● One 100 kVA. 11 kV./440 Vs. ON cooled station transformer. ● Five—three Phase, 1500 MVA. 110 kV. solenoid operated type OKG. 7 Bulk Oil Circuit Breakers. ● Two—three Phase, 150 MVA. 11 kV. solenoid operated cubicle type OLD. 3B Oil Circuit Breakers. ● Nine—three Phase, 25 MVA.440 V. type OB. 3 Air Circuit Breakers. ● Main and Auxiliary Control Panels. ● One Horizontal Shaft 125 kVA. House Alternator Set complete with exciter.

Other hydro-electric installations in India equipped by "English Electric" are the Radhanagri, Nizamsagar and Sarda power Stations. Hydro-Electric equipments have also been supplied or are being supplied for the Power Stations at Bhira, Hirakud, Rihand, Sengulam, Papanasam and Mettur.

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Hydro Power Development in Greater Mysore

By K. SEETHARAMIAH,
B.E., C.P.E.T. (I.I.Sc.), A.M.I.E. (Ind.), Am. A.S.C.E., Mem. I.A.H.R.
Assistant Professor, Indian Institute of Science

With the formation of the greater Mysore State from 1st November, 1956 by the addition of the Kannada speaking areas of the Bombay, the Madras and Hyderabad states and the inclusion of the small state of Coorg with the older Mysore state, the power map of the Mysore State has undergone a very drastic change and in this paper an effort is made to give in brief the water power potential and the possible scope for the development of the water power resources in the state.

It is a very well known fact that Mysore has been the pioneer state in India in the development of Hydro Electric power. The waters of the Cauvery river was harnessed for the development of power as early as 1904. The power developed was supplied to the Kolar Gold Fields over a distance of about 96 miles at 66,000 V. Actually it is at the same period that America also started the development of Hydro-Electric Power but they are far ahead of us. In India, due to various reasons, mainly the British Government, who were ruling us, were more interested in the exploitation of the country for their benefit and did not worry themselves for the development of the country. But for the Kolar Gold Mines which was worked by a British firm probably we would not have started the Hydro Power Plant at Sivasamudram as early as 1904. In this paper an endeavour is made to briefly survey the water power potential that existed in the old Mysore and the additional power potential that has been added to be state by the formation of bigger Mysore, the possible scope of development and interconnecting the system to South India Grid.

Hydro Electric Power Potential in South India

India is not blessed with large deposits of coal or oil. Actually coal has to be conserved for metallurgical processes and cannot afford to be used for power. The oil resources are very meagre and cannot be counted at all. But India is blessed with mighty rivers, the Ganges, the Brahmaputra, the Godavari, the Tapti, Narmada, Mahanadi, Krishna, Cauvery and their streams and many other smaller streams. The snow deposits in the Himalayas are a source of inexhaustible power in India.

In order to assess the Hydro Electric Power potential in India, Hydro Electric Surveys were conducted in 1921 and the power potential of the undivided India and Burma was estimated at 5.6 m.kW. on a minimum flow basis. The Central Water and Power Commission undertook detailed surveys and have estimated the power potential of India at 33.3 mkW. at 60% load factor. When the investigations are completely done it is quite possible that the power potential would be much more. Based on the surveys of the Central Water and Power Commission, the total power potential of South India is 10.49 mkW. The Western ghats which intercept the South West monsoon provide good storage sites and also have got very great drops which could be used for the development of power. The Hydro Power developed in India is hardly a million kW and one could appreciate the enormous task ahead to develop the power in our country.

It has already been mentioned in the beginning that Mysore was the pioneer State to launch on the Hydro Electric power development. The original Mysore had an area of about 36,000 sq. miles and the important rivers, flowing in the area were the Cauvery, the Tunga, the Bhadra and the Sharavati. More than half of the area of Mysore is plains and the western portion, called the Malnad, has heavy rainfall during the monsoon months. By proper planned storage of the monsoon rain waters it has been possible to develop a large block of power. The four valleys for development are the Cauvery valley, the Tungabhadra, the Varahi and the Sharavati. The Cauvery valley when fully developed can give about 138,000 kW. of power. The power potential of Tungabhadra valley was rather poor with only 17,000 kW at Lakkavalli. But with the inclusion of Bellary district in Mysore, the Tungabhadra dam has come to Mysore and consequently the power potential of Tungabhadra valley available for Mysore has increased to 87,400 kW. This does not include the Hyderabad portion of the Tungabhadra dam. When this is added the power potential of this valley will further increase as will be explained later. The Varahi valley which is estimated to give about 150,000 kW is not yet investigated for the development. The Sharavati river, the only river which runs west in the old Mysore state has very great potential power and it has been estimated that it could safely give 8,63,500 kW. Thus it could be seen that the water power potential of the old Mysore state stood at about 1.1 m.kW. out of the total potential of peninsular India of 10.49 m.kW.

The Cauvery power scheme

The hydro power plant at Sivasamudram on the

Cauvery river, located about 80 miles below the cauvery falls was built in 1902 and the orginal installation comprised of 6 small generating sets of 750 kW. each. The river Cauvery, not being a perennial stream, a storage reservoir was built at Krishnarajasagara for the development of irrigation in the valley and also to assure the required flow for power development. With the increasing power demand in the state the Sivasamudram power station underwent a series of modifications and additional installations were put in and today it has a capacity of 42,000 kW. comprising of 4-6000 kW. and 6-3000 kW. generating sets. The available head at the station is 412 ft. and the continuous discharge at the power plant is 900 cusecs.

With the increase in the power demand in Mysore state and also due to the outbreak of World War II demand for power increased and in order to develop power as quickly as possible it was decided to divert a small portion of the water from the Sivasamudram to Shimsha where a fall of about 50% more is available. This project called the Shimsha New Project was taken up and two units with a total capacity of 17,200 kW. were installed and they were commissioned in 1939. As the Sivasamudram station is getting old and outdated there is a proposal to gradually reduce the capacity of the power plant there and divert all available water to Shimsha. When this is done the total installed capacity would be 67,500 kW. Inspite of the addition of more units at Shimsha it is worthwhile to run the Sivsamudram station during the rainy season and develop seasonal power. The Shimsha project which is another project in the Cauvery valley when completed will utilise the waters of Shimsha river which is not yet utilized and could give 65,000 kW. of electrical energy.

The Cauvery waters after turning the wheels at Shivasmudram and Shimsha drops down at a place called Mekedatu, before it gets into the Madras state and this drop is about 230 ft. available for power and this would ultimately give power of 40, 500 kW. The Shimsha new project further development and the Shimsha project New Station and the Mekedatu power scheme are yet to be taken up.

With the increase in demand in power supply it was decided to take up the final investigations of Jog power scheme and launch on the project. The history of the Jog power scheme dates as far back as 1916 when the then Chief Engineer Kadambi investigated in detail the possibilities of power development. Sri M. Visveswaraiah pursued the investigations and prepared a scheme for the development of electrical energy to supply power to the Mysore Iron and Steel Works. Mr. Forbes, the Chief Electrical Engineer to the Government of Mysore, studied the demand of power in Mysore state and recommended to the Government of Mysore that if Jog power scheme is delayed there will be acute power storage in the state and that the development of Mysore would be hampered. The Government sanctioned the execution of the project and the works were started in 1939. The construction of a dam to impound 25 000 m cft. of water at Hirebhasagar, a diversion dam at Kargal and a power channel with balancing reservoir and forebay and penstocks to the power station at the foot of the gorge are the various important structures built in connection with the scheme. The first stage of the development was for the installation of 4 impulse turbines of 12,000 kW. each. But even before the completion of the first stage the power demand of the State dictated the second stage to be taken up; four additional units of 18,000 kW. each were installed and have been working since 1954. With the completion of the 2nd stage of the Jog power scheme, the installed capacity of the Sivasamudram, Shimsha and Jog power stations have reached 1,79,200 kW. The load growth in the state has been found to be so phenomenal that it was feared that the development of the State would be retarded if additional power is not made available to the state by developing the power potential in state.

Project Sharavati Valley project

The existing Jog Falls Hydro-Electric project is making use of only 25,000 m. cft. of water and generating 120,000 kW. of energy. The latest investigations and the hydrological studies have indicated that the rainfall varies from 56.55 inches to 320.23 inches and catchment area that could be utilized is 901 sq. miles in Mysore state. The actual yield as calculated during the year 1945 to 1955 has indicated variations from

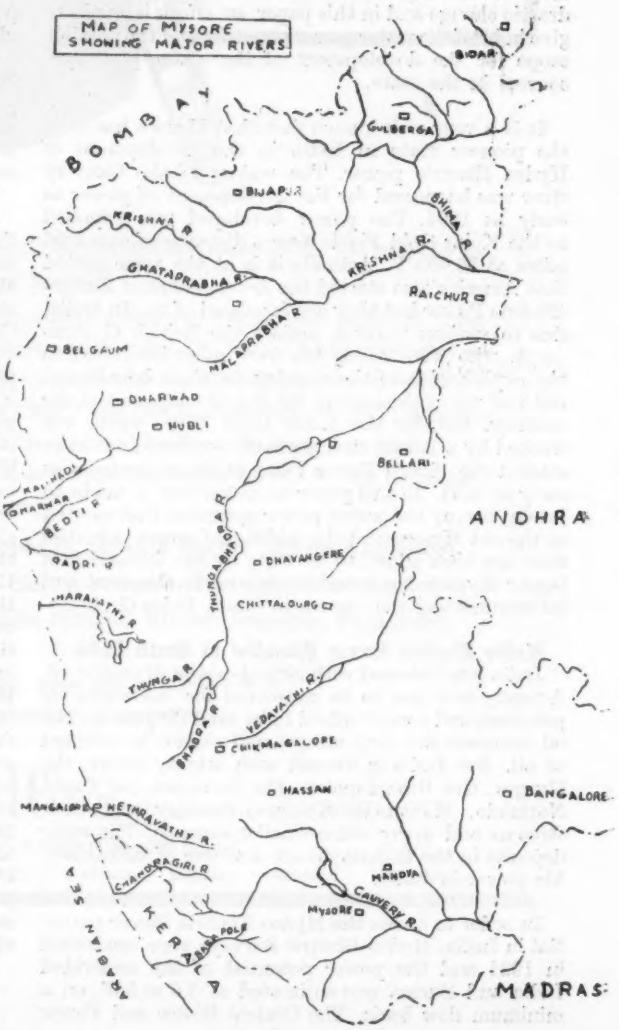


Fig. 1

1,24,958 m.cft. in 1952 to 2,58,000 m.cft. in 1946. On the basis of studies of gaugings and rainfall data of the entire catchment, the average inflow at the present Kargal Aniout site has been found to be 1,79,350 m.cft. which works out to a dependable average discharge of 5700 cfs. In addition to the main Sharavati river, the Talakakle stream, a tributory to the Sharavati river has a catchment of 18 sq. miles and lies in very heavy rainfall area and the average yield for the period of 56 years has been found to be 5800 m.cft.

Based on the data available of the Sharavati valley it has been found to be feasible to store about 1,56,633 m.cft. which can give an assured discharge of 4,500 cft. The total installed capacity including the power station at the New dam site and the existing Mahatma Gandhi Power Station would be 8,63,500 kW. installed.

The salient features of the Sharavati Valley Project consists of construction of a dam about $1\frac{1}{2}$ miles higher up the Kargal anicut to impound 1,50,000 m.cft., a water conductor system consisting of open channels, two tunnels, a balancing reservoir across Talakakle stream, forebay with provision for 10 pipe outlets. Each pipe is designed for a discharge of 690 cusecs. In the ultimate stage of development there will be 10 units of each 71.000 kW. capacity. When the Sharavati valley project is completed to the capacity of the entire basin, it would be delivering 710.000 kW. at the new station in addition to 1,20,000 kW. at the existing Mahatma Gandhi Power station and 33,500 kW. at the dam site station.

The intergation of Bellary district into Mysore state brought a part of the Tungabhadra dam and a portion of the canals to Mysore and with it the Hydro power also. The dam power station on the right side and the canal power station about 15 miles below the dam each when fully developed would give 36,000 kW. of electrical energy at each place.

The Lakkavalli project on the river Bhadra is expected to give 17,000 kW. of electrical power when the power station at the dam site is built.

The Krishnarajasagara dam on the river Cauvery has been provided with penstocks in the dam and they can be utilised for the development of a small quantity of about 5,000 kW. which may be a seasonal power for the development of a few industries round about Mysore.

Another scheme which is not yet fully explored in the State is the Varahi-Chakranadi. This river has its source in the heavy rainfall area of Malnad and flows towards the west. The preliminary surveys conducted by the Mysore Electricity Department has confirmed the technical feasibility of the scheme for harnessing the river. This project has a head of 1575 ft. and power draft of 600 cfs. and this when developed could give 150,000 kW. at 60% load factor.

From the above paragraphs it could be seen that Mysore state with its area of about 36,000 sq. miles in the older set up has a water potential of about 1.1 million kW. of energy out of which the present development is 179,200 kW.

With the addition of the Kannada speaking areas of Bombay, Madras, Hyderabad and Coorg the area of Mysore has gone upto 72,720 sq. miles with a population of nearly 19 million. This enlargement of the state has not added any appreciable quantity to the existing electrical power stations except the small hydro plant at Gokak. But the addition of the Bombay Karnataka, Hyderabad Karnataka, parts of Madras and Coorg have brought along with it a lot of Hydropower potential. In addition to the increased catchment area and length to Tungabhadra river, new river basins have been added to the state. They are the Krishna, the Bheema, the Ghataprabha, the Malaprava, the Kalinadi, the Barapole and innumerable

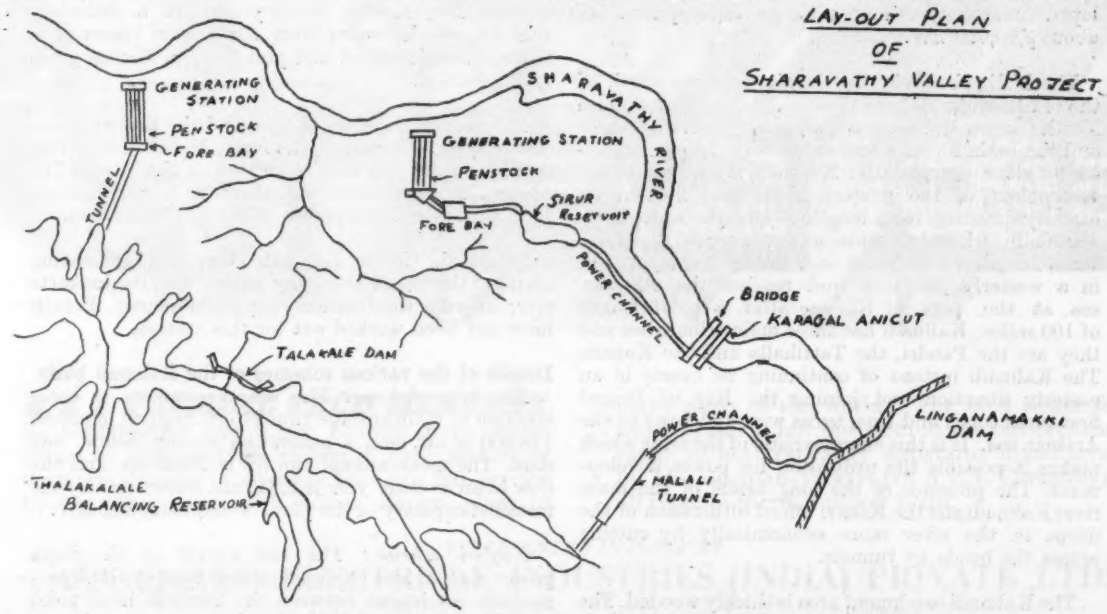


Fig. 2

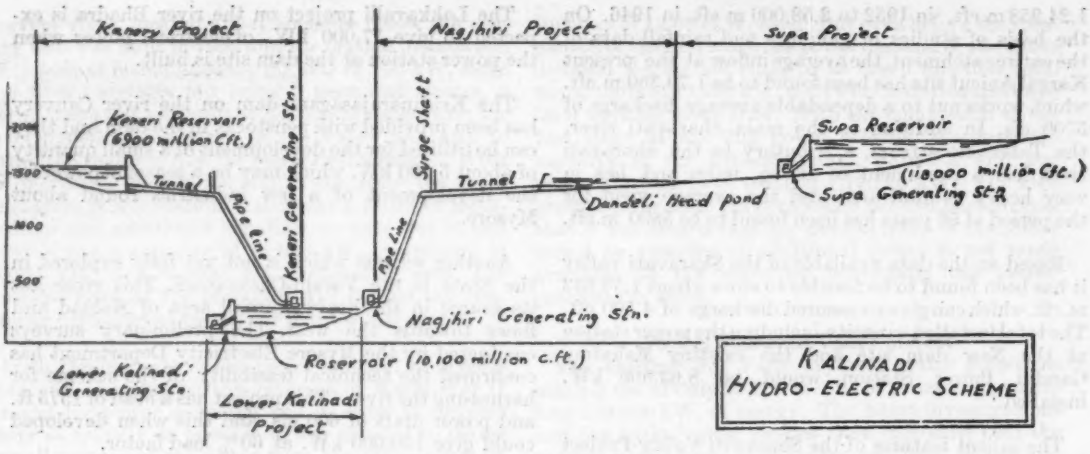


Fig. 3

small streams which flow to the Arabian sea from the western ghats. In the following paragraphs the Hydro power potential that has been added will be briefly described.

The Kalinadi basin

The Kalinadi basin development has been examined by the Electrical Grid Department of the Government of Bombay. The detailed investigations were conducted by the Associated Electrical Industries, Consulting Engineers, and the reports are very promising. The Surveys conducted are of a preliminary nature and it has been shown that a power potential of 6,90,000 kW. could be obtained from the basin. Detailed investigations may prove a higher potential for the development. The idea of harnessing Kalinadi waters for power development was thought of as early as 1921 by P.L. Bowers and he recommended a limited development of 80,000 kW. but the recent investigation conducted shows that the scheme is flexible and could be developed in stages with an ultimate development of about 5,90,000 kW.

The Kalinadi basin lies in the extreme south of the old Bombay state in the districts of Dharwar and North Canara and cover a total area of 1,870 sq. miles and the basin forms a broken plateau deeply dissected by river courses. The Kalinadi river rises in the escarpment of the western ghats and flows in an easterly direction for a length of 40 miles upto Bommanahalli where it takes a south westerly course for a length of 30 miles and finally swings round in a westerly direction and reaches the Arabian sea at the port of Karwar after a total length of 100 miles. Kalinadi has three main tributaries and they are the Pandri, the Tattihalla and the Kanari. The Kalinadi instead of continuing its course in an easterly direction and joining the Bay of Bengal first turns south and then turns west and flows to the Arabian sea. It is this characteristic of the river which makes it possible the utilization for power development. The presence of the long bends of the main river Kalinadi and the Kaneri afford ultilization of the drops in the river more economically by cutting across the bends by tunnels.

The Kalinadi catchment area is thickly wooded. The geology of the area is promising and the basin affords a good number of sites for storage dams and good drops are available to generate power.

The catchment has its rainfall varying from 300" in the west to about 40" in the eastern portion of the basin. The hydrological studies and the dam sites investigated show that it is possible to store 1,28,000 m.cft. at Supa 7,600 m.cft. on Kaneri and 11,900 m.cft. at the lower Kalinadi dam.

Scheme of development : This scheme is very flexible. The Supa reservoir would be the main reservoir whose water would be utilised through three power stations in series and they are the Supa, the Nagjiri and the lower Kalinadi. A perusal to the diagramatic section showing the proposed method of development shows the main reservoir at Supa and a power plant at the dam site. The tail water of the Supa power station is collected at Dandeli head pond from which a tunnel drops down the water to the Nagjiri power station. The Kaneri development is a tributory scheme and the water from the Kaneri reservoir is taken through tunnel and pipe lines to Kaneri generating station.

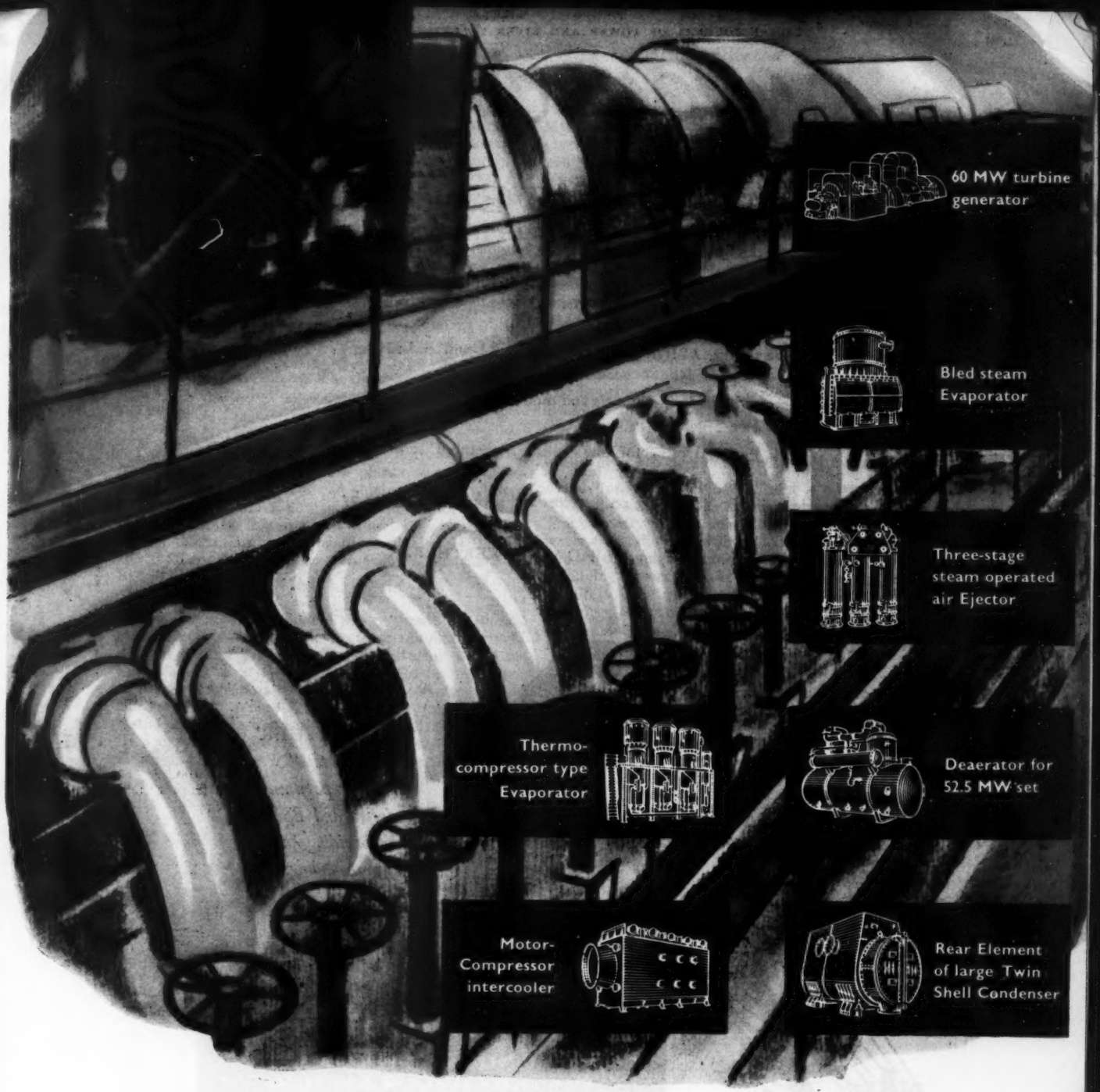
The tail waters of the Nagjiri and the Kaneri power stations are collected at the lower Kalinadi reservoir and a power plant can be located at the dam. The above three reservoirs and the four power stations form the main development of the Kalinadi basin.

Below the lower Kalinadi dam and generating station, the small tributary called the Baginakatte river afford a small scheme for development. Details have not been worked out for this station.

Details of the various schemes of the Kalinadi basin

The Supa Scheme: This scheme consists of construction of main storage dam 275 ft. high to impound 118,000 m.cft. and a generating station below the dam. The mean annual run off is 2,940 cfs. and the flow in an average year is 2,855 cfs. Based on this the installed capacity of the plant would be 90,000 kW.

Nagjiri scheme: The tail waters of the Supa power station and the unregulated flow of the intermediate catchment between the Dandelli head pond and the supa reservoir is made use of in the scheme.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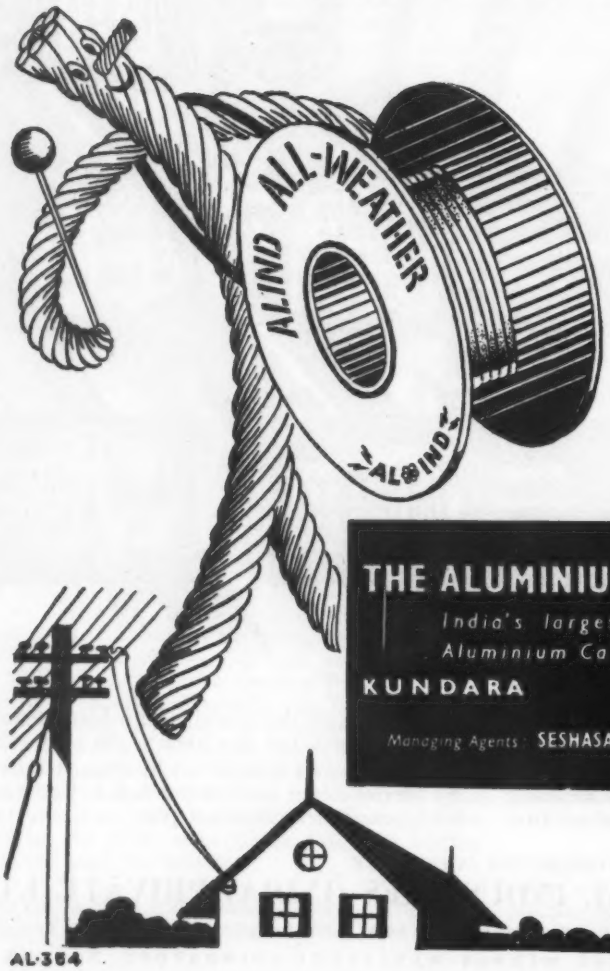

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The water from the Dandeli head pond is conveyed through tunnel and penstocks to the power station at the confluence of the Nagjhiri Nalla and Kalinadi. By the regulated water supply from Supa reservoir the mean flow in an average year is 3,540 cfs. and in a dry year 2,820 cfs. The head available is 1,005 ft. and the installed capacity of this plant would be 350,000 kW.

The Kaneri Scheme: This is a tributary development. The catchment area at the dam site is 114 sq. miles and annual rainfall is 154". Mean annual run off is 905 cfs. Run off in an average year is 525 cfs and in a dry year 450 cfs. The proposed height of the dam would be 250 feet and the capacity of the lake would be 7,000 m.cft. Tunnel and pipe line lead the water to the power plant. The head available is 1,170 ft. and the installed capacity of the plant would be 75,000 kW.

The lower Kalinadi Scheme: The tail waters of the Nagjiri and the Kaneri power plants and the water available between the power station and the lower Kalinadi dam a mean flow of 4,645 cfs. in an average year or 4,090 cfs in a dry year would be available for power. Maximum nett head available would be 185 ft. The plant can have an installed capacity of 75,000 kW.

In addition to the above 4 power plants it is possible to develop another plant on the Baginakatte river, another tributary of Kalinadi. This station would be the smallest plant and this plant could be built first to supply the necessary power for the construction of the remaining power plants. Next would come the Kaneri, next the Supa and lastly the Nagjiri plants. Of course any phased development could be settled depending upon the load development in the area.

The Tungabhadra power project.

Consequent on portion of Hyderabad joining the Mysore state the power plant at the dam site would give 36,000 kW. of additional power in Tungabhadra project making the power potential of the Tungabhadra project 108,000 kW.

Barapole Hydro Electric Project.

Another promising Hydro power project in the new Mysore state is the Barapole Hydro Electric Project in Coorg. Detailed investigations and surveys have been conducted by the Government of Coorg and it has been estimated to give 18,000 kW at 0·6 load factor when the river is fully developed. The water conductor system gives the various details of the scheme. The catchment area of the stream is 100.5 sq. miles and has an annual rainfall of about 150" to 200". The hydrological studies indicate that a continuous discharge of 650 cusecs would be available for power generation. This yield is on a low side, and on a more liberal side, 25,000 m.cft. could be obtained which would give a continuous yield of 710 cfs. for power.

The dam proposed on the river is a composite dam 4,760 ft. long and 279 ft. high above the bed level. The capacity of the reservoir is 16,300 m.cft. The water from the reservoir is led on to a balancing reservoir through a tunnel 14,480 ft. long. From the balancing reservoir, the low pressure penstocks of 43,200 ft. long upto surge tank and 4055 ft. long from the surge tank to the power station convey the water to the machines. The gross head available at the power site is 1,727 ft.

The tail waters of the first power station could through a suitable water conductor system be used to develop additional power, by utilizing the drop of 500 ft. The tail waters of the station could be used for developing irrigation in Malabar to an extent of 30,000 acres.

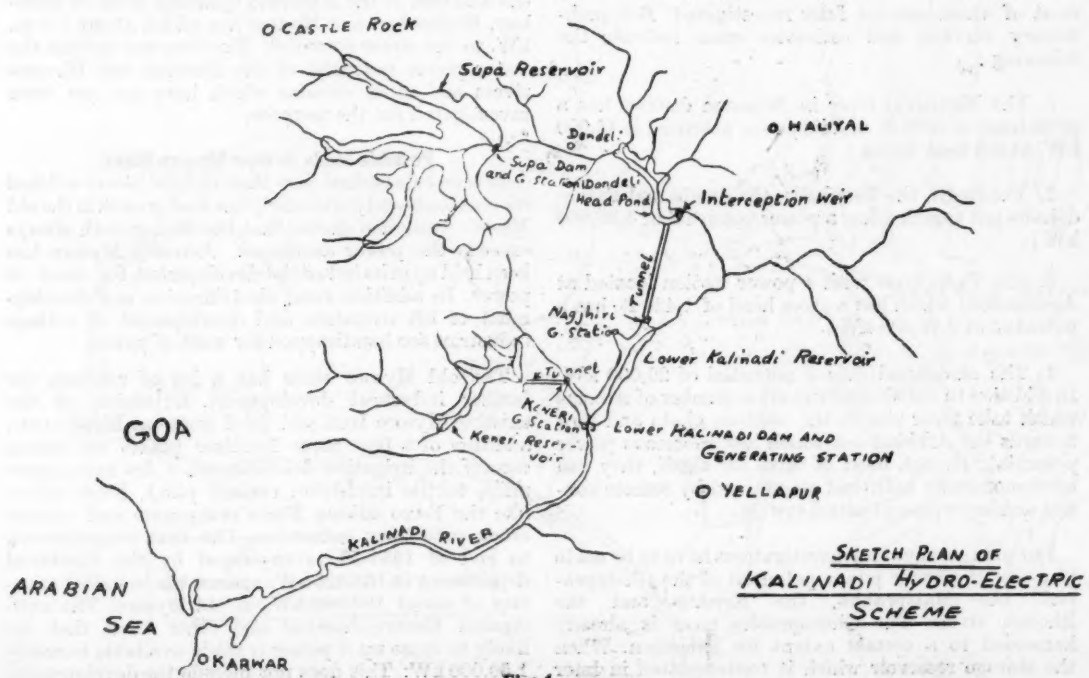

Fig. 4

SCHEMATIC DIAGRAM OF
SHARAVATHY VALLEY HYDRO-POWER
PROJECT
WATER CONDUCTOR SYSTEM

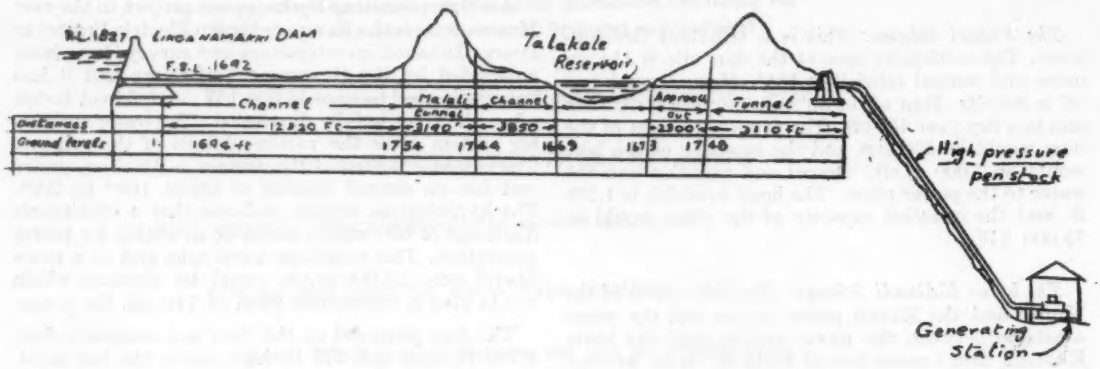

Fig. 5

Both the first and the second stages of development would develop 180,000 kW.

The benefits of this scheme are many. The Coorg district is purely agricultural, paddy and coffee cultivation. The district is rich in forest wealth which is not utilized. If power is made available in this area we can expect a number of paper mills, tile factories, saw mills etc., to come up in addition to providing electricity for rural electrification, irrigation pumps, water supply etc. In addition to the Hydroelectric power potential of Kalinadi and Barapole rivers, there are a number of other streams that flow west, most of which are not fully investigated. But preliminary surveys and estimates made indicate the following :

1. The Mahadayi river in Belgaum district has a gross head of 1600 ft. and its power potential is 48,000 kW. at 0.6 load factor ;

2. The Bedti, the Tattihalla, the Sanda and Patnadahalla put together has a power potential of 4,20,000 kW ;

3. The Tadri river with a power station located at Agnanashini which has a gross head of 1,425 ft. has a potential of 2,10,000 kW ;

4. The chakranadi has a potential of 20,000 kW. In addition to the above there are a number of streams which take their rise in the western ghats and flow towards the Arabian sea which has enormous power potential. Though most of them are small, they can be economically built and maintained by remote control and supervisory control system.

Detailed surveys and investigations have to be made to assess the water power potential of the Ghataprabha, the Malaprabha, the Krishna and the Bheema rivers. The Ghataprabha river is already harnessed to a certain extent for irrigation. When the storage reservoir which is contemplated in later stages are built, enormous power can be obtained from this river.

The Krishna and Bheema rivers which have come into Mysore state do not possess good sites for power development but it may be possible to develop small blocks of power by installing low head plants along the river and make use of the waters that are led down into the river from the Koyna reservoir for the irrigation development in the famine stricken areas of Bijapur district. As already mentioned in the earlier paragraphs, the water power potential of the old Mysore state is estimated at about 1.1. m. kW. and the addition of the Kannada speaking areas of Bombay, Hyderabad and Madras has added about 1.5 m. kW. to the power potential. This does not include the water power potential of the Krishna and Bheema rivers and other streams which have not yet been investigated for the purpose.

Possible loads in New Mysore State.

It is an established fact that electric power will find its own loads and particularly the load growth in the old Mysore state has shown that the load growth always exceeds the power developed. Actually Mysore has been held up in its industrial development for want of power. In addition rural electrification and development of lift irrigation and development of cottage industries are handicapped for want of power.

The old Mysore state has a lot of resource for further industrial development. Extension of the existing Mysore Iron and Steel works at Bhadravati, addition of a few more fertilizer plants for taking care of the irrigation development, a few more paper mills, textile industries, cement plant, Ferro alloys like the Ferro silicon, Ferro manganese and various other subsidiary industries. The firm commitments to end of 1955-56 as envisaged by the Electrical department is 163,520 kW. against the installed capacity of about 180,000 kW. in old Mysore. The anticipated Electro-chemical and other loads that are likely to come up if power is made available is nearly 1,50,000 kW. This does not include the developments

of the new areas added to Mysore. India has launched a big industrial development programme and the country has to develop rapidly. Electric power is of primary importance to carry out the programme.

Both the Government of Mysore and the Government of India appreciated the position of Mysore with regard to power and have taken up the Sharavati valley project first stage for the development of 14,2000 kW. of electrical energy.

The greater Mysore is likely to change the entire power development programme and load demand. With regard to power supply and development of industries the Karnatak areas of Bombay, Hyderabad, South Canara and Coorg are very backward in in electrical development and industries. Except a few towns, almost all the villages and towns in the area have not got electric power. The forest and mineral resources of the Belgaum, Dharwar, North Kanara, South Canara and Coorg are very rich and they have to be exploited if the state has to develop all round. It is impossible to neglect any part of the state. More than industries we have to ensure amenities to the people like protected water supply, sanitation, electric light for every home in our country. The areas of Hyderabad state and the districts of Bijapur and Bellary often suffer due to famines and failure of rains. The only solution for this is the assured water supply for irrigation. The use of irrigation pumps has to be made popular in the areas of deficit rainfall. The irrigation development in Bijapur district which was contemplated in the Koyna project of Bombay state which envisaged the installation of very big pumping plants for pumping water to the canal has to be thought off very seriously. In the design of the Koyna project, a certain amount of water has been earmarked for the irrigation in the Krishna valley and power estimated at about 10,000 kW. for pumping the large quantities of water was contemplated from the Koyna power station. As one connected with the Koyna project for about five years where I had the opportunity to survey a lot of the transmission lines for the pumping plants, I would like to stress the importance of taking the irrigation project by pumping the Krishna waters in stages for irrigation in Bijapur district.

Need to take up more hydel schemes in the State

In order to take up the development of the greater state it will not be possible to depend on the existing hydro power plants and those which are taken up for construction. It will be necessary to start simultaneously a few more hydro power schemes in Mysore. Though the power potential of Sharavati valley is quite enormous, it will take some time before full development could be expected. According to the load forecast it could be seen that there is more load than power that is expected to be got in the first stage. So till the further stages of the Sharavati valley project are taken up it is very hard to expect power supply for the development of the new areas that have got into Mysore.

In order to achieve a systematic all round development in the greater Mysore it is absolutely necessary to start the Kalinadi project in the Dharwar district and the Barapole in Coorg. The Kalinadi project and the Barapole project have been worked out in detail. The Kalinadi project, as the already been mentioned before, is a very flexible scheme involving the construction of four dams and five power stations. The Baginakatte project which is the smallest of the group could be started first to supply small power and could be followed by the Kanari project which would give about 90,000 kW. of power. As the load is developed in the area the Supa, the Nagjiri and the Lower Kalinadi projects could be developed. If this station

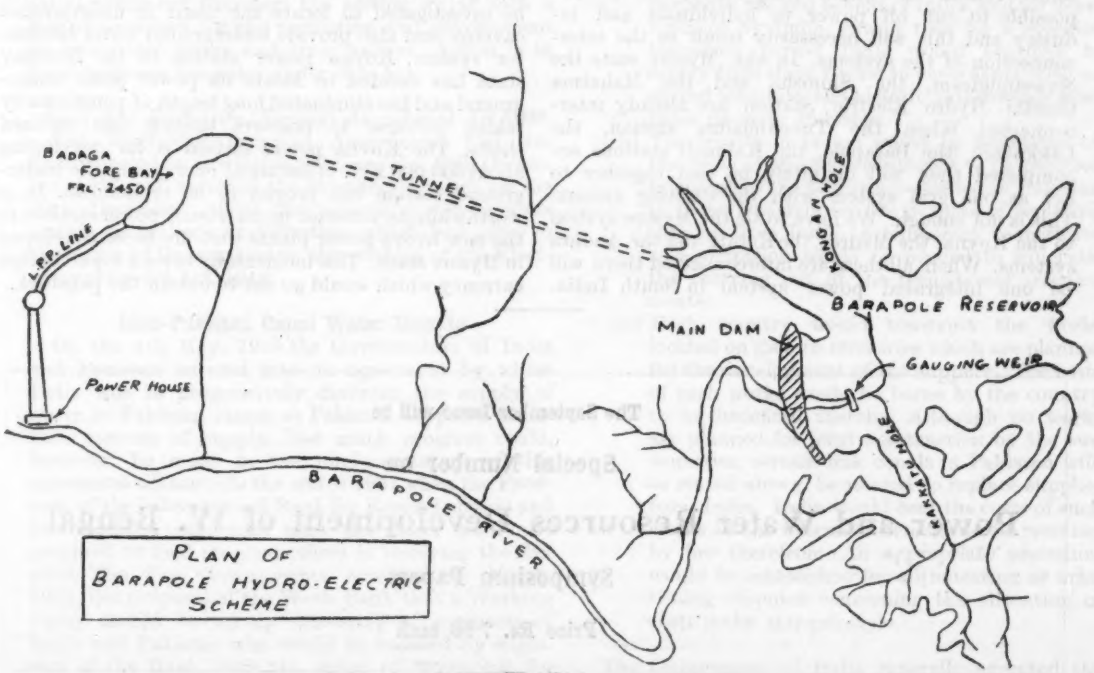

Fig. 6

is given the top priority, the districts of Dharwar, North Canara, Bijapur, Belgaum and the districts of Raichur, Gulburga and Bidar could be developed without delay.

The Barapole project in Coorg district cannot also be delayed any longer. This power station when completed could supply power to Coorg, South Canara and a few districts of the old Mysore state.

The power stations of the Tungabhadra project do not give much power to Mysore as a major portion of the power will have to be given to Andhra State but still when all the three power plants of the Tungabhadra project are completed it could meet the needs of Bellary district and a small part of Raichur district.

As and when the demand for power increases the other rivers mentioned above will have to be tackled and it is very hard to say at this stage which have to be given priority.

Interconnecting of Systems and exchange of power

It has always to be borne in mind that India inspite of its different types of people, different languages, different customs is one as a nation and any development will have to be considered in the broader interests of the nation. Though the various stages have boundaries to mark their territory, it is not proper to have boundaries in power supply industry. For the progress of India industrially and economically it is absolutely necessary to supply power from one area where it is in abundance to an area of scarcity. In order to achieve this all the power plants should not only be interconnected to act as a grid system but should be interconnected to power plants of other states also. An interconnected system is the healthiest and dependable system in power supply. A few of the power stations may have to be closed for some reason or other temporarily. It is not possible to cut off power to individuals and industry and this will necessarily result in the interconnection of the systems. In the Mysore state the Sivasamudram, the Shimsha and the Mahatma Gandhi Hydro Electric Station are already interconnected. When the Tungabhadra station, the Lakkavalli, the Barapole, the Kalinadi stations are completed they will definitely be tied together to act as one grid system with the existing system. This is not enough. We have to tie the Mysore system to the Koyna, the Madras, the Kerala and the Andhra systems. When all these are interconnected there will be one integrated power system in South India. This has to be done at some stage or the other and the earlier it is done the better.

Before concluding the paper it is felt desirable to state the importance of electric traction in South India. India in general and South India in particular do not have much coal. It is not possible to afford to burn a lot of coal in the boilers for running the railways. Except for the Singareni coal in Hyderabad large quantities of coal have to be handled over long distances which is not only a big burden for railways but also very costly. The cheap hydro electric power in South India should give impetus to railways to electrify the system. A small country like Switzerland has more than 4,000 miles of electric railway. With our industrial development it will be necessary to have quick and economical transport system. In India this could be achieved by electric traction. The heavy electrical industry has already contemplated the manufacture of Electric locomotives and this should give fillip for the electric traction in South India.

In the Hydro Electric projects the Civil Engineering Works consume a big share of the total expenditure. The penstock pipes are the costliest. In all our future projects every effort should be made to minimise the use of penstocks and use instead pressure tunnels. The tunnelling technique has reached such a stage of perfection that tunnelling could be done in any type of rock and there is no limitation for the lengths of tunnels. Another development that we have to catch up with other countries is the adoption of underground power stations. These are useful from the point of view of protection from aerial bombardments and they have proved economical. In Norway and Sweden it is a legislation that power plants of more than 2,000 kW. capacity have to be as far as possible underground. The big schemes like the Sharavati valley, the Barapole, the Kalinadi should be investigated to locate the plant in underground caverns and also provide underground water conductor system. Koyna power station in the Bombay state has decided to locate its power plant underground and has eliminated long length of penstocks by taking recourse to pressure tunnels and inclined shafts. The Koyna power station is for developing about 600,000 kW. of electrical energy and the underground station has proved to be economical. It is worthwhile to consider underground power stations in the new hydro power plants that are to be developed in Mysore state. This incidentally saves a lot of foreign currency which would go out to obtain the penstock.

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Report of the Ministry of Irrigation and Power

The following are extracts from the Report for the year 1956-57

Functions and Staff

A separate Ministry of Irrigation and Power was constituted in 1952 in recognition of the growing importance of the irrigation and power sector in the development programme of the country. This Ministry is responsible for laying down the general policy for the development of Irrigation and Power resources and for flood control measures. It assists the State Governments in the preparation of integrated programmes for the development of water and power and co-ordinates the supply of men and materials to the various projects. It formulates measures to ensure efficiency and economy in the execution of these projects. The Ministry also keeps a watch over the progress of works against targets and of costs against estimates.

Legislation

(*i*) *The Inter-State Water Dispute Act*, 1956.—The Inter-State Water Dispute Bill was passed by the Lok Sabha on the 11th August, 1956, and received the President's assent on the 28th August, 1956. The Act provides for adjudication of disputes relating to the waters of inter-State rivers and river valleys. Action is in hand to frame the rules under this Act.

(*ii*) *The River Boards Act*, 1956.—The River Boards Bill was passed by the Lok Sabha on the 11th August, 1956, and received the President's assent on the 12th September, 1956. The Act provides for the establishment, in consultation with the State Governments concerned, of River Boards wherever the Central Government considers the setting up of such a Board necessary for the regulation and development of inter-State rivers and river valleys. Action is in hand to frame the rules under this Act.

(*iii*) *The Electricity* (*Supply*) *Amendment Act* 1956. —The Electricity (Supply) Amendment Bill was finally passed by the Rajya Sabha on the 19th December, 1956, and received the President's assent on the 30th December, 1956. The amending Act removes certain anomalies and difficulties which had come to the notice of Government in the working of the Electriticy (Supply) Act, 1948.

Indo-Pakistan Canal Water Dispute

On the 4th May, 1948,the Governments of India and Pakistan entered into an agreement by which India was to progressively diminish the supply of water to Pakistan canals as Pakistan tapped alternatives sources of supply. Not much progress could, however, be made in the implementation of this agreement till towards the end of 1951 when the President of the International Bank for Reconstruction and Development suggested that the Bank would be prepared to lend its good offices in resolving the dispute. The two Governments accepted in March, 1952, the proposal of the Work Bank that a Working Party should be set up consisting of engineers of India and Pakistan who would be assisted by engineers of the Bank, with the object of preparing, for development of the water resources of the Indus region, so that the river supplies effectively available to each country would be increased substantially beyond what they had ever been.

The initial meeting of the Working Party was held in the office of the World Bank at Washington in May-June, 1952. The second meeting was held from December, 1952, to January, 1953, partly in Karachi and partly in New Delhi. The object of the meeting was to exchange certain studies prepared by both India and Pakistan. The remaining studies were exchanged at Lahore on February 24, 1953 and at New Delhi on March 18, 1953.

The final meeting of the Working Party was held in Washington from September 8,1953. The technical experts of India and Pakistan tried, for almost five months, to prepare an agreed plan, These efforts did not however, succeed. On February, 5, 1954, the Bank, finding that further discussions were not likely to prove fruitful, presented a proposal to the Working Party which, in its view, would produce a fair and economic result for both the countries. The salient features of the Bank proposal are as follows :—

(*i*) The entire flow of the Western rivers (Indus, Jhelum and Chenab) would be available for the exclusive use and benefit of Pakistan, and for development by Pakistan, except for the insignificant volume of Jhelum flow presently used in Kashmir.

(*ii*) The entire flow of the Eastern rivers (Ravi, Beas and Sutlej) would be available for the exclusive use and benefit of India, and for development by India, except that for a specified transition period India would continue to supply from these rivers, in accordance with an agreed schedule, the historic withdrawals from these rivers in Pakistan.

(*iii*) The transition period would be calculated on the basis of the time estimated to be required to complete the link canals needed in Pakistan to make transfers for the purpose of replacing supplies from India. A temporary cooperative administration would be needed to supervise the carrying out of the transitional arrangements.

(*iv*) Each country would construct the works located on its own territiries which are planned for the development of the supplies. The costs of such works would be borne by the country to be benefited thereby. Although no works are planned for joint construction by the two countries, certain link canals in Pakistan will, as stated above, be needed to replace supplies from India. India would bear the costs of such works to the extent of benefits to be received by her therefrom. An appropriate procedure would be established for adjudicating or arbitrating disputes concerning the allocation of costs under this principle.

The Government of India generally accepted the

Bank Proposal, but Pakistan did not accept it. The talks, therefore, ended in a breakdown. The Government of India, however, informed the Bank of their readiness to consider new arrangements for working out a comprehensive plan on the basis of the Bank proposals as soon as Pakistan accepted it. They also offered to enter into an agreement for a transitional period which would enable developments to proceed in both countries on an agreed schedule as envisaged in the Bank Proposal.

After a further exchange of views with the two Governemtns, the Bank extended an invitation to the Prime Ministers of India and Pakistan to resume discussions for the purpose of working out, without commitment, and for consideration by the two Governments, a detailed engineering plan for the use of the Indus waters, taking the division of waters proposed by the Bank as a starting point. The two Governments accepted the Bank's invitation and discussions were resumed with effect from December 6, 1954, in Washington, on the basis of the new terms of reference proposed by the Bank. As a result of the resumed discussions, three Agreements between the Governments of India and Pakistan for *ad hoc* Transitional Arrangements for Kharif 1955, Rabi 1 55-56 and for the period of April 1, 1956 to March 31, 1957, were signed on the 21st June, 31st October 1955, and 24th September, 1956, respectively. In pursuance of these agreements, Pakistan has been conveying supplies from the Western rivers through the link canals in Pakistan in replacement of supplies received from the Eastern rivers.

On May 21, 1956 the World Bank handed to the representatives of India and Pakistan, an *Aide-Memoire* for the consideration of the two Governments. As proposed in the Bank's *Aide-Memoire* the two Governments agreed to extend the co-operative work, through the good offices of the World Bank up to the 31st March, 1957.

Owing to the unprecedented floods in October, 1955, extensive damage was caused to canals, including link canals, in West Pakistan. Similar damage was caused on our side also. At the request of the Government of Pakistan, a team of Bank Engineers, and a delegation of Indian Engineers visited West Pakistan from 26th November to 11th December, 1955, with a view to surveying and assessing the extent of damage caused to the irrigation works, and to determining rehabilitation priorities for repairs to them. This was followed by another visit in December, 1956, by a team of two representatives of the World Bank and the Special Commissioner for Canal Waters and the Deputy Special Commissioner from India.

Flood Control Measures in the Eastern Regions of India and Pakistan

In August 1955, the Prime Minister of Pakistan suggested that the Governments of India and Pakistan should co-operate in a common endeavour for the control of floods in the Eastern regions of India and Pakistan. This suggestion was welcomed by the Government of India and a team comprising four senior engineers visited Karachi in September 1955, for preliminary discussions regarding flood control measures in East Pakistan. As a result of these discussions the Government of India agreed to supply relevant data and give flood warnings during the monsoon to the East Pakistan Government. This was followed by a meeting held in New Delhi on the 24th August, 1956, between the Minister of Irrigation and Power and Planning and the Pakistan Minister of Industries and Commerce.

The discussions at the Conference related to the co-operation between the Governments of India and Pakistan for the control of floods in the eastern regions of the two countries, and to finalise certain procedural matters and manner of exchange of information necessary for measures for flood control in the two eastern regions. The Ministers of India and Pakistan authorised the Chairman of the Brahmaputra River Commission (India) and the Chairman of the East Pakistan Flood Commission (Pakistan) to correspond with each other direct on technical matters and request for such information as may be of assistance in tackling flood problems in the two regions. The Conference also approved of the following recommendations made by the Chairman of the two Commissions :—

(*i*) Flood warnings to be given from Dibrugarh, Gauhati, Patna, Silchar, Gomti, Khewai and Dhalai from India to Pakistan ;

(*ii*) Flood warnings from Atrai in Pakistan to be given to India ;

(*iii*) Heavy rainfall data from Shillong to be transmitted to Pakistan ;

(*iv*) Heavy rainfall data from Sylhet and Habiganj in Pakistan to be sent to India ; and

(*v*) India will endeavour to furnish such other information relating to the Brahmaputra valley or other assistance as may be considered necessary by the two Chairmen for formulating flood schemes in East Pakistan.

Assessment of Irrigation Potential

The overall study of the irrigation potential of various river basins was continued. The study involves the following three stages :—

Stage I.

Determination of the possible project sites and preparation of preliminary basin-wise irrigation potential reports based on available data.

Stage II.

Collection of hydrological data at key points of river basins, reconnaissance survey of project areas and preparation of final basin-wise reports.

Stage III.

Detailed investigations at selected sites and preparation of detailed project reports.

Draft reports under Stage I have been prepared for the following river basins :—

(*i*) *West-flowing rivers (falling into the Arabian Sea)* :—

(*a*) River basins of the former Travancore-Cochin State.

(*b*) Weat-flowing rivers of Madras and Bombay States below the Tapi River.

(*c*) The Narbada and the Tapi river basins.

(*ii*) *East-flowing rivers (falling into the Bay of Bengal)* :

(*a*) The Tambraparni and the Vaigai river basins.

(*b*) The Cauvery river basin.

(*c*) The Mahanadi and other river basins between the Ganga and the Godavari.

(*iii*) *Ganga River Basin*

The Chambal river basin—The draft reports so far prepared have been sent to the State Governments for their comments. The reports will be finalised after these comments are received.

Navigation

The navigation report in respect of the Mahanadi river is nearing completion. The West Bengal Government's 'City Extension Scheme' for the reclamation of North Salt Lake Area of about 4 sq. miles was studied and comments offered. The tentative proposal of the Nagarjunasagar Control Board to make the project's right bank canal navigable was examined and comments were sent to the Board.

A Master Plan for inland navigation has been prepared with the object of linking the waterways flowing into the Arabian Sea and the Bay of Bengal. The Master Plan includes the following schemes :—

(1) Linking of the Narbada with the Ganga.
(2) Linking of the Narbada with the Godavari.
(3) Linking of the Tapi with the Godavari.
(4) Linking of the Ganga with the Mahanadi.
(5) Connecting Calcutta with Bangalore by coastal canals.

An estimate for preliminary investigations for schemes (1) and (2) above is under consideration.

Assessment of Water Power Resources

In connection with the systematic and detailed assessment of water power resources of the country, the fourth volume of the Hydro-Electric Survey of India dealing with the power potential of the Ganga Basin was published. Studies of the Brahmaputra basin are in progress.

Assistance was rendered to the various State Governments in the examination of tenders for the plant and equipment required for the power stations under their control. The more important amongst these are Bhakra (Punjab), Koyna (Bombay), Rihand (U.P.), Ganderabal and Mohara (Kashmir) and the Nangal 3rd unit (Punjab).

Project Reports of a number of hydro-electric schemes proposed by the State Governments and other authorities for inclusion in the second Five Year Plan were examined with regard to their power generation aspect.

Small selfcontained Units

In connection with the development of a small self-contained hydro-electric generation unit, which would be useful in supplying cheap electric power to remote areas in the hilly regions of the country, the Commission have completed the experimental model of Mitchell-Banki Turbine. During the year under report, work on the manufacture of the proto-type turbine was taken up at the National Physical Laboratory and the design of a suitable automatic speed load governor for the turbine is being developed. A site for the experimental installation and tests has been selected in Himachal Pradesh and the Executive Engineer, Himachal Pradesh P.W.D., furnished with the estimates for the execution of the necessary civil works. Orders for a generator required for the purpose have also been placed through the Director General, Supplies and Disposals.

Rural Electrification Directorate

There were 6,500 villages in the population range of 0—10,000 enjoying the benefits of electricity at the end of the first Plan period. About Rs. 75 crores have been provided in the second Plan for electrification of about 10,000 small towns and villages. Rural electrification schemes of the various State Governments were examined in the Commission and necessary recommendations made.

In pursuance of the recommendations made by Irrigation and Power Seminars held at Roorkee and Srinagar in regard to rural electrification, follow-up action is being taken on :—

(*i*) The collection of data on the financial working of the electricity undertakings in both the public and private sectors in the States for conducting studies with a view to formulating proposals for the grant of subsidy for rural electrification schemes ;

(*ii*) Preparation of a long-term plan for rural electrification after an assessment of the financial requirements, the amount of subsidy that might become necessary, and the requirement of essential materials such as line supports, conductors, transformers, switchgear, etc. ;

(*iii*) Periodical progress reports on rural electrification schemes executed in the States.

As line supports required for rural electrification are in short supply in India, an agreement for their import to the value of 3 million dollars was entered into with the Technical Cooperation Mission authorities. Specifications for the materials were prepared in the Commission. Specifications were also finalized for the purchase of diesel generating sets from Canada under the Colombo Plan. Delivery of the line supports and the diesel sets is expected to commence shortly.

The question of supply of wood poles for overhead power lines was discussed at the meeting of the Board of Forestry held in Srinagar in June, 1956. It was felt that, with proper coordination between the Centre and the State Forest and Electricity Departments, the Indian forests would meet the entire requirements of 2 lakh wood poles. The Board recommended the setting up of a "Central Board of Wood Poles" for the purpose.

Load Survey and Load Development Directorate

A national load survey has been undertaken with a view to facilitating proper planning of additional generating capacity and correlating the same to the demand in each region The Directorate has completed the preliminary survey of the whole country. Reports showing the requirements of power under each category of load for each district have been issued during the year in respect of 15 States.

The results of the load survey indicate that there is a general consciousness in the country, including

remote villages in rural areas, of the advantages to be gained from the use of electric power. Consequently, the demand for power for cottage and small-scale industries in villages in much more than could be anticipated earlier. Similarly, in towns and cities, the tempo of industrialisation for medium and heavy industries has increased to such an extent that the targets set earlier, are expected to be exceeded in many cases. The results of the survey further indicate that the planned generating capacity of 3.4 million kW for the second Plan period will fall short of the demand, thus making it necessary to provide additional generating capacity and impose restrictions on new connections in some of the areas.

Co-operation from the bordering Himalayan Countries

The co-operation extended by the bordering Himalayan countries namely, Nepal, Bhutan, Sikkim and Tibet (China) in the work of investigations and collection of data continued to be encouraging. 44 rain gauges in Nepal, 14 rain gauges, 3 wireless stations and 9 river gauges in Bhutan and 3 rain gauges in Sikkim have so far been set up. Detailed surveys of the Teesta catchment in Sikkim are being carried out by the West Bengal authorities. Two dam sites in Nepal have been located and surveyed by the Bihar Government, one on the Bagmati at Nanthore and other on the Kamla at Chisapani. A reservoir site in Nepal has also been located by the U.P. engineers at Jalkundi on the Rapti and the Nepal Government have offered to give all facilities for detailed investigations.

The arrangements previously made with the Government of the People's Republic of China for the transmission of flood warning from Tibet continued during the 1956 flood season ; wireless messages about the hydrographic conditions at three main controlling points on the river Tsangpo (Brahmaputra) were sent by that Government whenever the discharge exceeded certain limits.

Power Research Institute

In August, 1955, a Committee was set up to formulate a programme for research work in respect of problems concerning power engineering development in the country for inclusion in the Second Five Year Plan. The Committee submitted its report in September 1956. Its recommendations are under examination.

Irrigation and Power Seminar

The Fourth Irrigation and Power Seminar was held at Hirakud from the 14th to 16th January, 1957 under the chairmanship of Union Minister for Irrigation and Power. The more important subjects discussed at the Seminar were :

(1) Report of the Rates and Costs Committee.

(2) Eradication of corruption.

(3) Silt in relation to Irrigation & Power projects ; and the role of Forests in Flood Control.

(4) Organisation and administration of river valley projects.

(5) Use of lime-mortar and lime pozzolan mortar in place of cement.

(6) Substitutes for steel in reinforced concrete construction.

(7) Experience gained from the execution of projects under the First Plan.

Rates and Costs Committee

The Report of the Rates and Costs Committee was discussed at the Fourth Irrigation and Power Seminar held at Hirakud. Final decisions on the recommendations contained in Part I of the Report will be taken in the light of the discussions. The more important of of the recommendations are given below :—

(*i*) Proper investigations should invariably be carried out before a project is taken up. This has not been the case with many of them.

(*ii*) Proper planning and estimation should be done by competent engineers before a project is sanctioned.

(*iii*) Estimates should be prepared in sufficient detail to enable the project authorities to exercise proper control over cost.

(*iv*) Costing cells should be introduced on all projects.

(*v*) A perpetual inventory of stores should be taken on all projects.

(*vi*) Manuals on costing and stores should be drawn up and Committee's recommendations on the subject be codified to enable all projects to adhere to a uniform pattern of accounting.

(*vii*) The life tables for equipment should be standardised. The Committee has made suitable recommendations in this regard.

(*viii*) The allowance for major repairs and overhauls should be put on standard footing.

(*ix*) Scales should be laid down for provision for fuel, stores, lubricants, and for labour required for equipment.

(*x*) Principal items of construction equipment should be standardised and early steps should be taken for their manufacture in the country.

(*xi*) A central clearing house should be formed immediately for the prompt disposal of all surplus equipment and stores on projects.

(*xii*) A system of incentives in the shape of overtime bonus and recognition of merit should be introduced on all projects.

(*xiii*) For the sake of coordinated development and economy in manpower and equipment, river valley projects should be made a central subject.

Part II of the Report relating to stores and other accounting procedures is under examination by the Comptroller & Auditor General of India.

In order to coordinate the costing work and to maintain, in the course of execution, a close watch on the

trend of rates of important items of work on different projects, a central cost accounting unit is being set up in the Central Water and Power Commission. Modifications, if any, to the existing arrangements recommended by the Rates & Costs Committee will be communicated to the State/Project authorities concerned for implementation.

Technical Personnel Committee

The final report of the committee which was set up in July, 1954, has been received and is under examination.

The sub-committee set up by the Co-ordination Board of Ministers under the chairmanship of the Union Deputy Minister for Irrigation and Power, to look into the general question of technical personnel for river valley projects has submitted its report to the Co-ordination Board of Ministers. The recommendations of the Board are awaited.

With a view to finding alternative employment for the staff rendered surplus on river valley projects nearing completion, an Officer on Special Duty has been appointed in the Directorate General of Resettlement and Employment. A scheme has been drawn up for the setting up of employment exchanges at various project sites in collaboration with the Ministry of Labour. An employment exchange was set up at Maithon in the Damodar Valley Corporation area to provide employment assistance to the Damodar Valley Corporation staff. Similar arrangements have been made at Bhakra-Nangal and Hirakud projects. Arrangements are in hand to set up employment exchanges at the Rihand, Koyna, Chambal, Nagarjunasagar projects etc., in consultation with the project authorities and the State Governments concerned.

Training

(*i*) *Fresh Engineering Graduates and Serving Engineers*—Under the Ministry's scheme for imparting practical training to fresh engineering graduates and serving engineers in the methods of design and construction of dams and large power plants at the Central Water and Power Commission and the Bhakra-Nangal, Hirakud and Damodar Valley Projects, two courses have so far been completed. The period of training is one year for fresh graduates and six months for serving engineers.

Only 11 candidates completed the first course for fresh graduates, as against 30 selected. In order to make the scheme more attractive and to ensure that the trainees did not leave the course before completion, the State Governments who were to sponsor the candidates for the second course were requested to offer them a guarantee of long term appointment in the States on completion of the training. 16 candidates were accordingly nominated by the State Governments but only five completed the training. The scheme did not prove a success. In order to make it workable, it has been decided to relax the condition regarding the offer of guarantee to the prospective trainees, as the State Governments met with practical difficulties in fulfilling this requirement. The question enhancing the stipend for the trainees is also under active consideration.

As regards the training of serving engineers, 7 officers completed their training in the first course and 9 in the second course against 15 or more provided for in the scheme.

(*ii*) *Operators and Machanics*—Two centres for imparting training to operators and machanics in the operation and maintenance of earth-moving machinery have been established at Kotah (Chambal) and Nagarjunasagar, respectively. Provision has been made for the training of 40 candidates at each centre, the period of training being one year. A stipend of Rs. 100 is paid to each trainee. This scheme is receiving aid under the T.C.M. Programme in the shape of equipment worth about $4,60,000 and technical services of 4 experts. Equipment worth about Rs. 13.45 lakhs has already been supplied and the services of the experts have been made available.

The training centre at Kotah started functioning with effect from the 1st November, 1955. During the first course, 26 candidates received training. The second course is now in progress and 36 candidates are undergoing training. The Nagarjunasagar training centre started functioning in June, 1956. 42 candidates are undergoing training. The question of setting up additional training centres to meet the increased requirements of such personnel for projects to be executed under the Second Plan is under consideration.

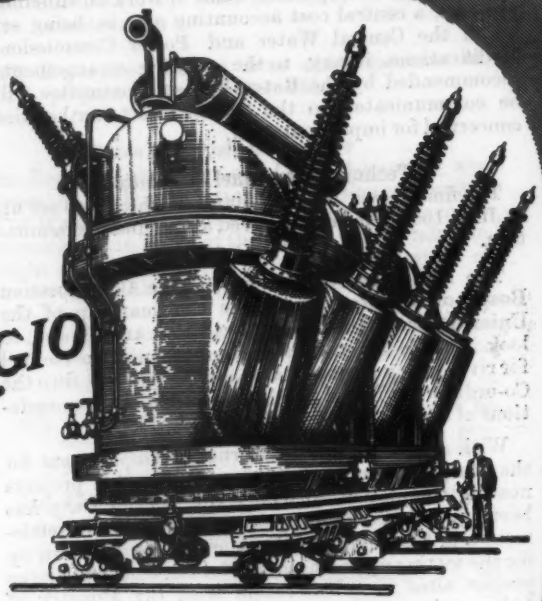
(*iii*) *Hot Lines Crew Training in India with T.C.M. Assistance.*—The scheme of Hot Line Crew Training with T.C.M. Assistance was sanctioned in February, 1956. The scheme contemplates setting up of two training centres for a period of two years—one at Ganguwal (Punjab) and the other at Bangalore (Mysore). Under this scheme, Indian workmen will be trained in handling special tools known as "Hot Line" tools. With the use of these tools, transmission lines can be maintained and the faults rectified without cutting the power supply.

National Projects Construction Corporation Private Ltd.

In order to ensure the optimum utilization of the available trained personnel and the machinery and equipment rendered surplus on projects nearing completion and to assist State Governments who do not possess any adequate organisation for the execution of large projects, the National Projects Construction Corporation Private Ltd. has been set up. It was incorporated under the Companies Act on the 9th January, 1957. The Corporation combines the advantages of departmental construction with the flexibility associated with the execution of work by private construction agencies.

The nominal capital of the Corporation is Rs. 2 crores divided into 20,000 shares of Rs. 1,000 each. Seven States, *viz.*, Assam, Orissa, Rajasthan, Madhya Pradesh, Kerala, Bihar and Jammu & Kashmir have so far agreed to participate in the scheme and with the others the matter is still under correspondence. In view of the limited activities of the Corporation in the initial stage, it has been decided that the Centre should contribute Rs. 25 lakhs and that each of the the participating States Rs. 10 lakhs.

The Corporation has, as its first assignment, undertaken the execution of 2 aqueducts and a certain length of canal on the Chambal Project Canal system. Preliminaries are in hand such as construction of labour huts, procurement and transportation to site of machinery and transport vehicles, office and workshop arrangements, and arrangements for lime and other raw materials.



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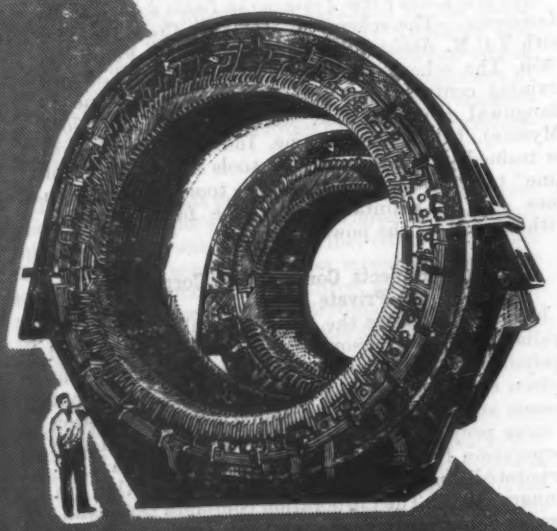

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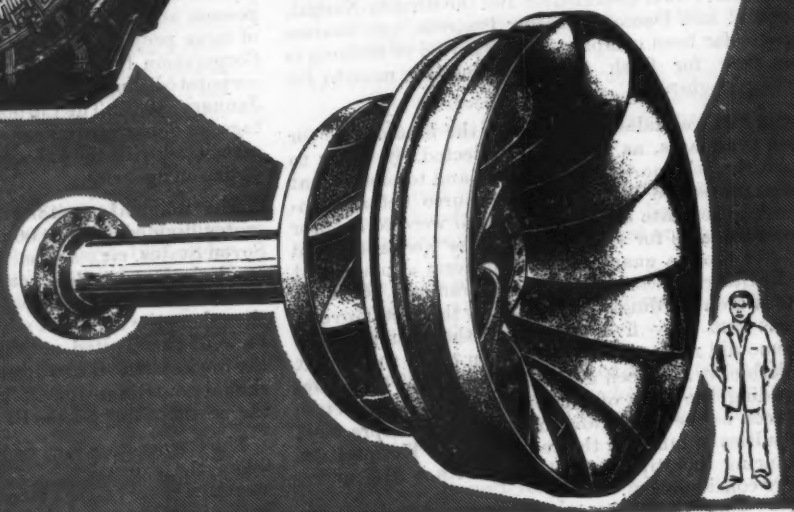

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SPHINX-35

Development of Electric Cable Manufacture

By CHARLES G. GORTON, A.I.R.I.

Cables for carrying electric current have only beed developed during a comparatively short period as compared to the development of other cables such as hemp cables, used for haulage purposes which were being produced hundreds of years ago. Electric cable manufacture can be said to have commenced during the nineteenth century following the succession of discoveries in the electrical field during that time. Nevertheless some of the processes of electric cable manufacture had their origin in the dim ages of the past. To trace these developments let us consider separately the conductor, the insulation and the protective covering of a cable.

The Conductor may be of any of the common nonferrous metals or in some exceptional cases of ferrous metal. It is usually assumed that wire is a modern product but in point of fact wire-making is a very ancient craft going back as far as is known for about five thousand years. The earliest wire production was in nonferrous metals, iron and steel being produced into the craft only a few hundred years ago. Ancient people were skilled in the production of gold, silver, copper and bronze wires, used mainly for ornamental purposes. It has been recorded that gold filament of.010 in. dia was produced, and it is believed that it was processed by hammering and not by drawing. It is thought however that some eastern craftsmen discovered how to draw wire with dies consisting of hardwood about the year 4,000 B.C. There is also some evidence that the Chinese about the same period used dies made of stone. About the 14th century A.D., wire production on a commercial scale was developed in Germany, where water wheels were used for motive power. About a century later, the wire industry was established in England, being brought over by craftsmen from Germany.

At the beginning of the twentieth century, the method of wiredrawing in use was the singlehole or bull-block. The dies were made by punching holes in steel plate. Rows of single capstans driven from a common backshaft were employed for drawing single lengths of wire and as each reduction was effected, the steel plate was replaced by a smaller one until the final size wire was attained. This method ofcourse was very crude and costly and the wire produced was of poor finish as judged by modern standards.

Due to the rapidly developing electrical field a demand arose for large quantities of copper wire and about the year 1,900 multiple die machines were introduced working at finishing speeds of about 250 feet per minute. Little progress was made on the design of these machines for about twenty years although some progress was made in increasing the drawing speed to about 350 feet per minute. The introduction of tungsten carbide dies about 1920 revolutionised the methods and machines for producing the wire and improved the quality of the finished wire. The next decade showed a continuous increase in drawing speeds but this was limited by the design of the machines. However, in 1930, one engineering firm produced both tandem and cone type machines with finishing speeds of 2000 feet per minute. Design has, ofcourse, advanced and improved since then but enough development had occurred to fix the technique now existing for wire drawing.

Stranding of the wires in the early days of electric cable manufacture followed closely the method of the rope makers and the machines used for rope making were adapted for wire stranding. These machines were of the welknown "sun and planet" type in which six bobbins of wire are rotated around seventh wire, the whole seven then being drawn off by a capstan into a take-up drum. With the increasing demand for cables, although it was realised that rope machinery was too slow, it was not until the first World War in 1914 that any change in the method of stranding was made. Enormous quantities of field telegraph cable were required for the forces on the Western Front and to meet this demand machines had to be designed to give greater output than was then possible on the 'sun and planet' type stranders. Accordingly a machine was designed in which six bobbins of wire were placed in tandem in a tube, the tube being rotated around the bobbins. The wire from each bobbin were being drawn off through a centering plate at the front end of the tube to a capstan and on to a take-up drum. The shape of the tube and the centering head resembled a torpedo and the first of the design were known as 'torpedo stranders'. Considerably greater speeds were possible with this type of machine as compared to the 'sun and planet' type, but many cable manufacturers were of the opinion that this method of stranding was unsuitable for trands consisting of more than seven wires and wires larger than 0.064 in., owing to the fact that the individual wires received a twist on the operation. About 1930, one cable manufacturer decided to try stranding nineteen wires by the tubular method and a machine was built to accom-

modate twelve spools of wire with a larger spool in the front part of the tube to accommodate the seven strand centre. This proved quite successful and since that time larger machines have been put into use. Within recent years tubular stranders capable of stranding thirtyseven wires have been introduced and are also proving successful. Coincident with the introduction of the tubular strander, another type of machine was introduced to produce finewire flexible conductors consisting of up to 110 wires. Strictly speaking, this method was not the true progressive 'multiples of six' layers. The machine was of novel design in so far that the spools of wires to be bunched were placed on a stand known as the "creel" from which they were drawn off through a centering die plate to a rotating tube in which was placed a take-up spool, the bunched wires being revolved inside the tube to give them a double twist. This method was almost universally adopted for the production of flexible conductors and although numerous improvements have been made and speeds increased, the principle remains the same today for flexible conductors.

An important development in strading was that of the 'shaped' conductor for paper mains cables. The strand instead of being circular in cross-section, was given a 'sector-shape' appropriate to the number of cores. This feature reduced to a minimum the space between cores and reduced the overall diameter of the finished cable. To avoid damage to the paper insulation when laying up, the shaped conductor is preformed so that it does not have to be twisted when laying up, the preforming or prespiralling as it is sometimes called, allows each core to fall naturally into its correct position. This process of preforming and shaping is done by means of a pair of revolving rolls at the front of the strander in place of the usual fixed split die.

The insulation of electric cables, which I will refer to as the 'insulant,' may consist, within reasonable limits, of any flexible nonconductive material. Fine wires as used in the early telegraph instruments were insulated with silk thread or cotton thread impregnated with bees wax. The machines used to apply the silk or cotton on the wire were those which at that time (about 1870) had been designed to cover loops of wire with cotton for ladies' crinoline dresses which were the fashion then. These machines were of simple design, a spool of cotton being rotated around the wire while the wire was being drawn off on to a capstan and take-up drum. One of these machines was still in use at the Silvertown factory up to the year 1924. The principle of rotating and winding the cotton around the wire still remains the same although many improvements in regard to speed and uniformity of covering have been made to the machine since those early days. For indoor wiring for lighting and leads to electric motors etc. rubber was adopted as the most suitable insulant. Generally, three layers of rubber were applied, pure rubber next to wire, then a layer of compounded rubber known as the separator, and overall another layer known as the jacket. The separator and jacket contained sulphur which when heated converted the natural rubber from a thermoplastic material into an elastic one. Vulcanised rubber has a certain amount of free sulphur, which blooms to the surface and as this would react on copper a thin coating of tin was applied to the copper wire. A further precaution was that next to the tinned wire was placed the layer of pure rubber containing no sulphur.

Two methods were originally employed to apply the layers of rubber to the conductor. For conductors up to 7/.064 in. the rubber was applied by passing the wire through grooved steel rolls, between the rolls and the conductor the layers of thin sheet unvulcanised rubber were fed. The grooved rolls under pressure forced the sheet rubber around the wire. This is termed longitudinal covering and the method is still extensively used today. After the rubber had been applied a layer of cotton fabric was applied in a spiral form to ensure that the plastic unvulcanised rubber did not deform before vulcanisation. The whole then was placed in a chamber known as a "cure" and subjected to steam under pressure for a certain period of time thus vulcanising the insulant. The other method used in conductors above 7/.064 in. was to apply the three layers of rubber and tape spirally around the conductor before vulcanisation. For many years relatively high percentages of sulphur and long vulcanising periods were necessary to vulcanise the rubber. With the co-operation of the rubber and chemical industry, certain chemicals known as 'organic' accelerators were made available in the early twenties. These accelerators enabled vulcanisation to take place in a much shorter time and with much less sulphur. This development eventually led to the abandoning of the pure rubber layer next to the tinned conductor. This in turn gave rise to another method of applying the rubber to the conductor, viz. by extrusion. The rubber compound in this method being fed into a machine in which a screw rotated carrying the plastic rubber to a crosshead through which the conductor was passed. Suitable dies controlled the amount of rubber forced around the wire. It should be noted that the method of extrusion of an insulant around a conductor was not new as it had been used many years before to apply gutta-percha to conductors used in submarine telegraph cables.

During the Second World War, even better accelerators were developed and where an old-fashioned rubber compound required two to three hours in live steam at about 140 deg. C to vulcanise, modern accelerated compounds can be vulcanised in fifteen to thirty minutes at the same steam temperature. If the temperature of the steam is raised to 180-200 deg. C., these compounds can be cured in a few seconds. This is the basis of the continuous vulcanisation process (known as C.V.) in which a vulcanising tube about 140-160 feet long containing live steam at about 200 lb pressure is coupled direct to an extruding machine. The past twenty years have witnessed the introduction of many synthetic materials, some of which are now used instead of rubber as an insulating material for electric cables. Among these materials are poly vinyl chloride (PVC) and polythene. With the advent of the Second World War and the consequent cutting off of the supply of natural rubber these synthetic materials were in great demand. They are applied to the conductor by the extrusion method.

Another development during the second World War was the introduction of a new type of field telegraph cable which superseded the old type consisting of copper and steel strands, insulated with rubber and braided. The new type consisted of single strand of

steel covered with polythene. It proved to be quite satisfactory in use, being light in weight, well insulated and strong. Its lightness and compactness enabled it to be easily paid out from an aeroplane.

Of the recent developments the use of PVC and polythene as insulants has a great advantage from the manufacturers' point of view in so far that no vulcanising is required ; thus a great saving in plant and labour can be achieved. Nevertheless there is a great reluctance on the part of the old established cable makers to abandon rubber as an insulant in favour of these new and modern materials mainly because it would make their existing rubber covering and vulcanising plant redundant.

For high voltage underground mains cables, impregnated paper has been used as an insulant from the very early days. Paper insulation was introduced towards the end of the nineteenth century and its use for high voltage began with Ferrantis famous ten KV cable laid from Deptford Power Station, London, to a station on the west end of London in 1890. His cable was made up of two concentric copper cylinders insulated from each other by about half an inch thickness of oil-impregnated paper. Naturally this was a very rigid cable. Since then however, there were many developments particularly in the use of stranded conductors to give greater flexibility. The method of manufacture is to spirally lap layers of paper in tape form over the conductor, in some cases as many as forty layers being applied to give the required thickness of insulation. The individual cores after paper lapping are laid up to form a multi-core cable, further layers of paper being applied over the laid up cores to act as a binder and to provide part of the common insulation to earth. Impregnation of the laid up paper cable is carried out by placing the cable in a steam jacketed tank which can be sealed and made airtight. All air and moisture is withdrawn from the tank and cable by means of a vacuum pump. Heated oil is then pumped in under pressure and allowed to cool under vacuum. After a certain period, varying from 12 to 24 hours according to the thickness of insulation to be treated, the cable is removed and lead covered thus retaining the oil between the layers of paper. One other method is to impregnate the papers with oil before applying to the conductor, and this method was—and I believe still is—used by one cable maker only. It is claimed that cables made by this method are non-bleeding and are eminently suitable for use in upright positions. Both methods described have been in use since the early days of cable manufacture and little change has taken place in the equipment used.

Finally to deal with the protective covering of cable. This may consist of any of the following : cotton braid impregnated with wax, lead sheath, rubber sheath, plastic material sheath, steelwire or steel tape. Braiding is done on machines adapted from those originally used to produce textile braids for decorative purposes. With a few minor improvements the process has remained the same since the commencement of cable manufacture. Lead covering is done on a press consisting of a container for the molten lead into which a ram hydraulically operated, enters and forces the semi-molten lead around the cable core. A further protection can be given by applying steel tape in spiral form around the lead sheath or alternatively a layer of steel wires may be laid around. Rubber sheathing as a protective covering was introduced and patented about 1910. It was known then as cab tyre sheathing or CTS, from the fact that the rubber used was of the same type as was used for the tyres of horsedrawn cabs in those days. Later, after the patent had expired, it was called tough rubber sheath or TRS. Within the last decade PVC has been extensively used for sheathing of cables. Both rubber and PVC for sheathing are applied by the extrusion method. One other protective covering which I have not mentioned is brass tape, this is used in the make up of submarine cables to afford protection against insect in the sea which penetrates the normal type of steel wire armouring used on submarine cables.

Yet another protective covering which is not generally known and up to the present little used, is aluminium wire but as far back as 1930 a cable was required, which had to be of the lightest construction, consistent with strength to carry power from the mooring mast to the giant airships R. 100 and R. 101 when the ships were moored and their own generators stopped. The Silvertown Company where I was then employed was given the job to design and manufacture the cable. Conventional copper conductors insulated with rubber were laid up and armoured with aluminium wire. This incidentally was my first introduction to the use of aluminium wire for cable manufacture.

(*Talk delivered at Kundara in May*, 1957.)

Dr D. N. WADIA ELECTED F.R.S.

A signal honour was paid to India in the election of Dr. D. N. Wadia, of the Indian Atomic Energy Department, to a Fellowship of the Royal Society, the most eminent scientific body in the world.

Dr Wadia's name was put forward some time ago by Fellows of the Society closely acquainted with his career in science, and in due course his qualifications were examined by the Council in comparison with those of other candidates who have distinguished themselves in the scientific field. As no more than 25 scientists may be elected to the Royal Society each year, candidates nominated by each section are subjected to a rigorous process of elimination.

The rules governing the submission of names and the election of candidates are very strict, and the identity of the proposers and seconders are not made public.

At the recent meeting of the Royal Society, presided over by Sir Cyril Hinshelwood, the name of Dr Wadia was mentioned with the recommendation of the Council that he be accepted as a Fellow of the Royal Society "for researches into the geological structure of the Himalayas."

Dr Wadia, who is Geological Adviser in the Department of Atomic Energy, was then unanimously elected to the Society's membership.

Development in the Design of Large Turbo-Generators

Associated Electrical Industries (India) Private Ltd.

In a constant endeavour to develop generating sets of better efficiency and lower capital cost, the capacity of turbo-generator sets in the U.K. has reached 200 M.W. per unit while developments are in progress for units of 275 M.W. and 550 M.W. capacity.

This article describes some of the features which have made possible the design of high efficiency, large capacity generating units.

Generators

With the increase in the generator capacity, the original cooling medium of air has been superseded by hydrogen gas, in order to improve the efficiency and reduce the size of the generator to manageable proportions.

Advantages obtained when hydrogen is used for cooling are :—

(1) Increase in generator efficiency resulting from a reduction in windage loss brought about by the use of hydrogen, which at a pressure of 1/2 lb/sq. in. gauge and normal operating purity has a mass only 1/10th that of air. This increase in efficiency may amount to 0.8% at full load, with further gains in economy at part load.

(2) Low and more evenly distributed temperatures brought about by the high thermal conductivity and heat transfer coefficients of hydrogen.

(3) Elimination of fire risk because hydrogen will not support combustion.

(4) Reduced maintenance because of the gas-tight and hence dirt-proof casing.

(5) Quieter operation because of the virtual elimination of windage noise and the heavy gas-tight enclosure.

(6) Simplified foundations, and additional space made available for auxiliary equipment because external air ducting, coolers and fans are not required.

The formation of explosive mixtures within the casing is avoided by maintaining the hydrogen purity at not less than 95%, well above the upper limit, during normal operation.

The formation of explosive mixtures during filling and emptying of the casing is avoided by introducing carbon dioxide as an intermediary gas whenever the the contents are changed from air to hydrogen or vice-versa.

To prevent the admission of air due to leakage the hydrogen in the casing is always maintained at a positive pressure above atmospheric. The machine may, of course, be designed for operation with gas pressure of 1 or 2 atmospheres gauge to take advantage of the improved cooling of the hydrogen at these pressures.

The ventilating gas is circulated through the generator casing in a closed system by fans mounted on the rotor. Four gas coolers are installed in the stator frame, flexibly mounted on rubber to minimise vibration of the water tubes.

To present the escape of hydrogen from the generator casing at points where the rotor shaft extends through the endshields, shaft seals of the thrust type are provided at each end of the machine.

Oil pressure in the seal maintains the sealing thrust and prevents the flow of hydrogen past the rotor shaft.

In the experience of the Company who were forerunners in the field of hydrogen-cooled generator development in the U.K., the operation of a hydrogen-cooled generator presents little additional difficulty to the operating staff.

During normal operation the casing pressures and seal oil pressure are maintained automatically at the required values. Since the hydrogen pressure is at all times maintained above atmospheric, the only way air can enter the gas system is via the oil employed to seal the shaft.

Considerable experience in America and the U.K. has indicated that hydrogen-cooled alternators can be operated with perfect safety.

The most potentially dangerous condition which could arise would be the formation of an explosive mixture inside the machine casing or inside any closed vessel or compartment forming part of the auxiliary gear. The formation of such an explosive mixture within the casing is avoided by the method of operation already described.

Even with hydrogen cooling the size and weight of a generator of 200 M.W. or greater becomes critical for existing transport limitations in the U.K. and shipping facilities for export.

In an attempt to further reduce the weight and size of large generators, liquid cooling of the stator has been introduced. Although liquid cooling has already been applied to some large generator stators, the cooling medium used has been oil which although satisfactory in many respects, has not the desired thermal capacity. Metropolitan Vickers Co. Ltd. have built an experimental generator using water as a cooling medium.

This is the first generator in the world to use water for stator cooling. To gain some experience with this type of cooling, the capacity of the generator was chosen as 30,000 kW, generating 11,800 volts at a speed of 3000 r.p.m., so that the generator could be coupled to a 30,000 kW turbine under construction at the Bold Power Station near Manchester. This station also has air-cooled generators for identical duty thus enabling a direct comparison to be made between

the performance of a water cooled and air-cooled machine. On this generator M.V. have carried out a considerable amount of research on the use of water for cooling the stator conductors.

The cooling water circuit for this design can be followed by reference to *Fig.* 1.

The maximum temperature rise of the distilled water was 2°C and the copper temperature rise would only exceed this by the water-to-copper surface temperature rise, which is only 2.20°C. With a pressure drop across the winding of 18 lb/sq.in. the power required to pump the water through the complete circuit was 8.8 kW. Finally a three-phase sudden

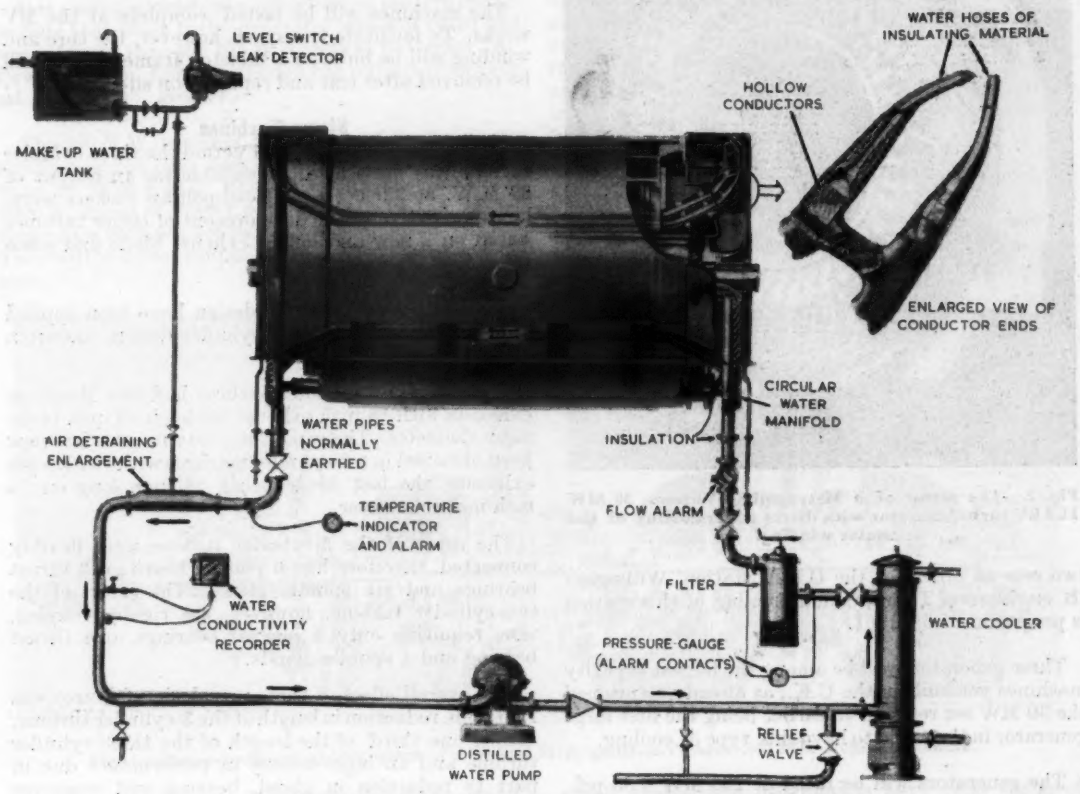


Fig. 1: Cooling water circuit for a water cooled stator winding

In this machine the flow of water is from one end of the stator to the other, through all the conductor strands in parallel. Water flows from a header pipe at one end of the stator, passing through separate tubes of plastic insulating material connected to each conductor. Similar tubes at the other end of the stator convey the water to an outlet header pipe. The actual windings are hollow tubular strands, which are transposed to reduce eddy currents.

Fig. 2 shows the end windings of the stator with the plastic tube connections to the circular water header pipe.

The generator has been subjected to all the standard work's tests, including open circuit and short circuit characteristics and losses. Distilled cooling water with a conductivity of 2.5 reciprocal megohms per c.m. cube was used. Although it might be thought that heavy losses would be caused by the use of water, the total loss in the water in the plastic tube connections was estimated to be less than 1 kW, during a 5-hour temperature test at approximately full load of 37.5 MVA, 11.8 kV, zero power factor. Even if Manchester tap water is used the losses are less than 10 kW. short-circuit test at full voltage and a high potential test of 24.6 kV for 1 minute between phases and to ground were carried out, again with water flowing through the conductors.

By reducing the size of the stator conductors, and therefore the space required to accommodate them the new cooling system marks a great advance towards reducing the overall size of large a.c. turbo-generators. In the earlier machines of the same rating, the air-cooled conductors have a temperature rise of about 65°C (measured by thermocouple between coils outside the insulation) for a current loading of 1835 A and with cooling air at 35°C, and the corresponding copper temperature is estimated to be about 115°C. The water-cooled conductor on the other hand has carried a current of 1750 A for 5 hours, after which the copper temperature was 29.2°C, the inlet distilled water temperature being 27°C. It is therefore capable of carrying a very much larger current within the permissible temperature limits for insulation in contact with the copper.

The feature of water cooling will be incorporated in the 200 M.W. turbo-generators for which M.V. have

Fig. 2.—The stator of a Metropolitan-Vickers 30 MW 11.8 kV turbogenerator with direct water-cooling of the stator winding.

two sets on order for the C.E.A. station, Willington 'B' on the river Trent. Commissioning of this station is programmed for 1961.

These generators will be among the largest capacity machines yet built in the U.K., as already mentioned the 30 MW set referred to earlier being the first large generator in the world to have this type of cooling.

The generators will be rated at 200 MW 0.85 p.f., 16.5 kV 3 phase, 50 cycles. As for the 30 MW generator, the water will be in direct contact with the live copper of the stator windings. The rotor will be cooled by hydrogen at a pressure of 30 lb/sq. in., the cooling gas will be circulated in a closed circuit ventilation system with standard Metropolitan-Vickers type coolers arranged longitudinally in the annular space between the core and the stator frame.

The machines will be tested complete at the MV works. To facilitate transport, however, the core and winding will be built on a skeleton frame, which will be removed after test and replaced on site.

Steam Turbines

In the immediate post-war period the three cylinder turbine was most readily available for an output of 60 M.W. at 3,000 r.p.m. Metropolitan-Vickers were, however, active in the development of larger turbines based on a new and longer exhaust blade and some other new features.

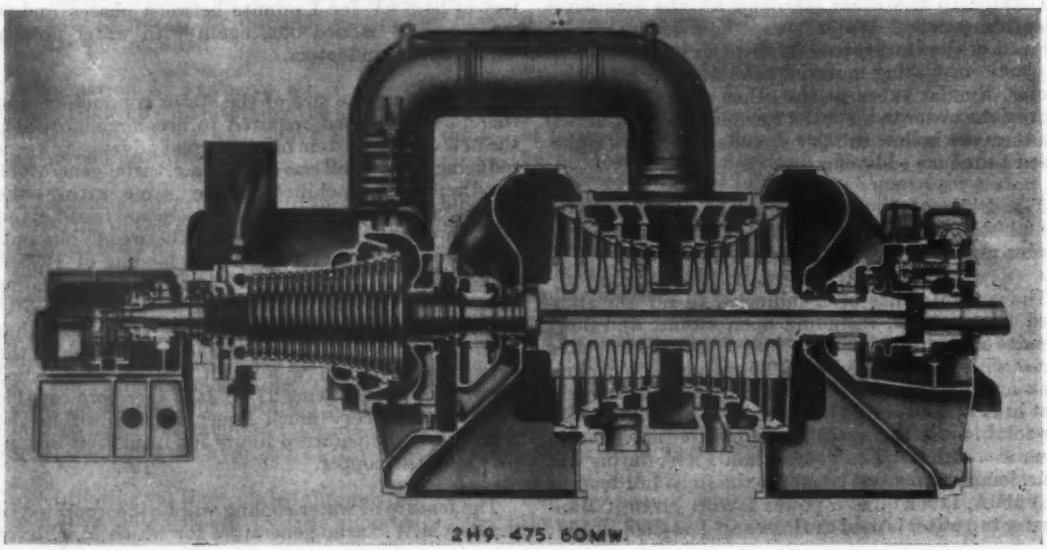
Some of these changes in design have been applied to a 60 M.W. turbine of 2 cylinder design, shown in *fig.* 3.

The original 3 cylinder turbine had two Baumam exhausts with 18 inch exhaust blade on 63 inch blade mean diameter. The same total leaving area has now been obtained in a 2-cylinder machine with two simple exhausts, the last blade being 21 inch long on 75 inch mean diameter.

The rotor of the 3-cylinder turbine were flexibly connected, therefore had 6 journal bearings, 3 thrust bearings and six spindle glands. The rotors of the two-cylinder turbine, however, are rigidly coupled, thus requiring only 3 journal bearings, one thrust bearing and 4 spindle glands.

The overall effect of these new design features was 12 ft. 6 in. reduction in length of the 3-cylinder turbine, almost one third of the length of the three cylinder turbine and an inprovement in performance due in part to reduction in gland, bearing and crossover losses.

Fig. 3: Cross sectional arrangement of a typical Metropolitan-vickers 60 MW turbine.



These new features have made the design of 200 M.W. single axis turbine possible.

Two turbines of this capacity are on order with Metropolitan-Vickers for the Willington 'B' station in conjunction with water cooled generators referred to above.

It is also of interest, as a reflection on modern design to note that these turbo-generator sets will be 20 feet less in length than the 105 M.W. sets at Battersea "A" Power Station, London, though the output from each set will be 90% greater.

The 200 M.W. turbines, *Fig.* 4, are of the 3-cylinder rigidly coupled type designed for initial steam conditions of 2350 p.s.i.g. 1050°F, with reheat steam at 1000°F, speed at 3000 r.p.m. and will be the largest single axis turbines yet built by Metropolitan-Vickers. They will be direct coupled to the water-cooled generators.

operations has depended to a large degree on the judgement of the operating staff as to what is happening in the machine and on their observation and skill in exercising control of the factors involved.

It has become clear that it is desirable to provide the operator with instruments to indicate and to record the quantities involved, thereby to ensure a more rigid and at the same time a safer and easier adherence to the correct operating technique. Moreover, when extended over the whole running period the recording provides invaluable data for the designer and enables certain irregularities, which might develop in the plant, to be more easily recognised and rectified before damage could result.

A series of investigations has been carried out by the Company to explore, by methods developed for the purpose, the degree and nature of the factors involved, particularly in regard to axial expansion and shaft eccentricity, and this work has formed the basis on

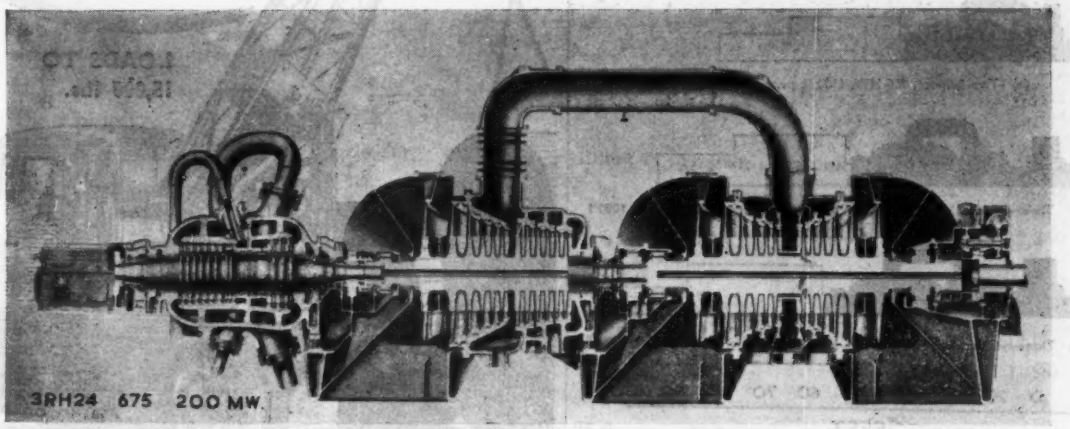


Fig. 4.—Cross-sectional arrangement of a typical Metropolitan-Vickers 200 MW Reheat Turbine.

To illustrate the trend in increasing turbo-generator capacity and its effect on efficiency and size, Table I records the basic operating conditions, the improvement in heat consumption and the decrease per M.W. in weight, in length and in engine room plan area with improvement in design and increase in unit capacity.

Fig. 5 gives a pictorial impression of the relative size of standard British turbo-generator units ranging from 30 M.W. to 200 M.W.

The employment of progressively higher pressures and temperatures associated with large turbines has produced, or accentuated, certain problems connected with thermal expansions of the rotor and cylinder. It is characteristic of turbine plant that the higher the operating conditions the greater will be the weight or mass of the cylinder relative to the rotor. It follows that in plant designed for high steam conditions the rotor is liable to be subjected to more rapid changes of temperature than the cylinder. To avoid excessive distortion of rotor or cylinder, or excessive differential expansions, a defined procedure should be employed at starting and after shutting down.

In the past the satisfactory performance of these

which appropriate instruments have been designed and manufactured.

An over-rapid axial expansion of the rotor relative to the cylinder or vice versa may cause axial interference at the blading or glands, and in starting up it is essential to keep such expansion within defined limits by heating the cylinder concurrently with the gradual and uniform heating of the rotor. Measurement of the relative axial expansion are taken between a point on the shaft and an adjacent portion of the cylinder at the end remote from the thrust bearing, it being noted that the thrust bearing is at the high pressure end of the shaft.

In the starting up of high temperature turbines bending of the rotor due to unbalanced heating can cause serious vibration and often damage, and it is essential that a sufficient degree of uniformity of temperature be established and that the rotor shall be straight before the plant is brought to speed. This is effected by the admission of a small steam flow to the cylinder, concurrent with the barring round of the rotor. The eccentricity is usually measured on a part of the shaft near the extreme high pressure end, i.e. the end remote from the associated intermediate or low pressure cylinder or generator.

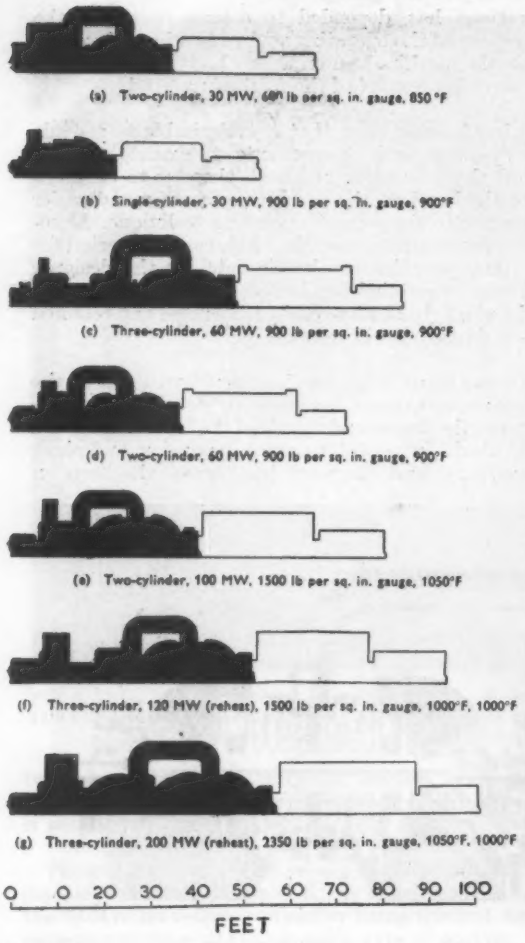

(a) Two-cylinder, 30 MW, 600 lb per sq. in. gauge, 850 °F
(b) Single-cylinder, 30 MW, 900 lb per sq. in. gauge, 900°F
(c) Three-cylinder, 60 MW, 900 lb per sq. in. gauge, 900°F
(d) Two-cylinder, 60 MW, 900 lb per sq. in. gauge, 900°F
(e) Two-cylinder, 100 MW, 1500 lb per sq. in. gauge, 1050°F
(f) Three-cylinder, 120 MW (reheat), 1500 lb per sq. in. gauge, 1000°F, 1000°F
(g) Three-cylinder, 200 MW (reheat), 2350 lb per sq. in. gauge, 1050°F, 1000°F
0 0 20 30 40 50 60 70 80 90 100
FEET
105181 P1/7

Fig. 5.—Contemporary British steam-turbine development.

Unless suitable precautions are taken on shutting down a turbine, there is a possibility of the rotor becoming bent on account of the quicker cooling of the bottom half, and to restart the machine before uniform heating has straightened it might result in serious damage.

The apparatus for recording these values comprises two separate recording equipments, built into the same cubicle to measure and record

(1) displacement of the shaft relative to the cylinder due to differential expansion or to any other cause, and

(2) shaft eccentricity

Each equipment consists of electromagnetic detectors suitably mounted on the turbine bearing pedestals and constructed and insulated to withstand the ambient conditions in which they operate, and electrical circuits which convert the displacements detected into currents which may be recorded.

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nes provides in addition for the electrical indication of turbine speed, kW output and vibration on each pedestal, and temperatures at different points of the cylinders.

By correlating the values indicated with this equipment, the turbine operator can arrive at a starting technique which brings the turbine on load in the shortest permissible time, without damaging this valuable piece of equipment.

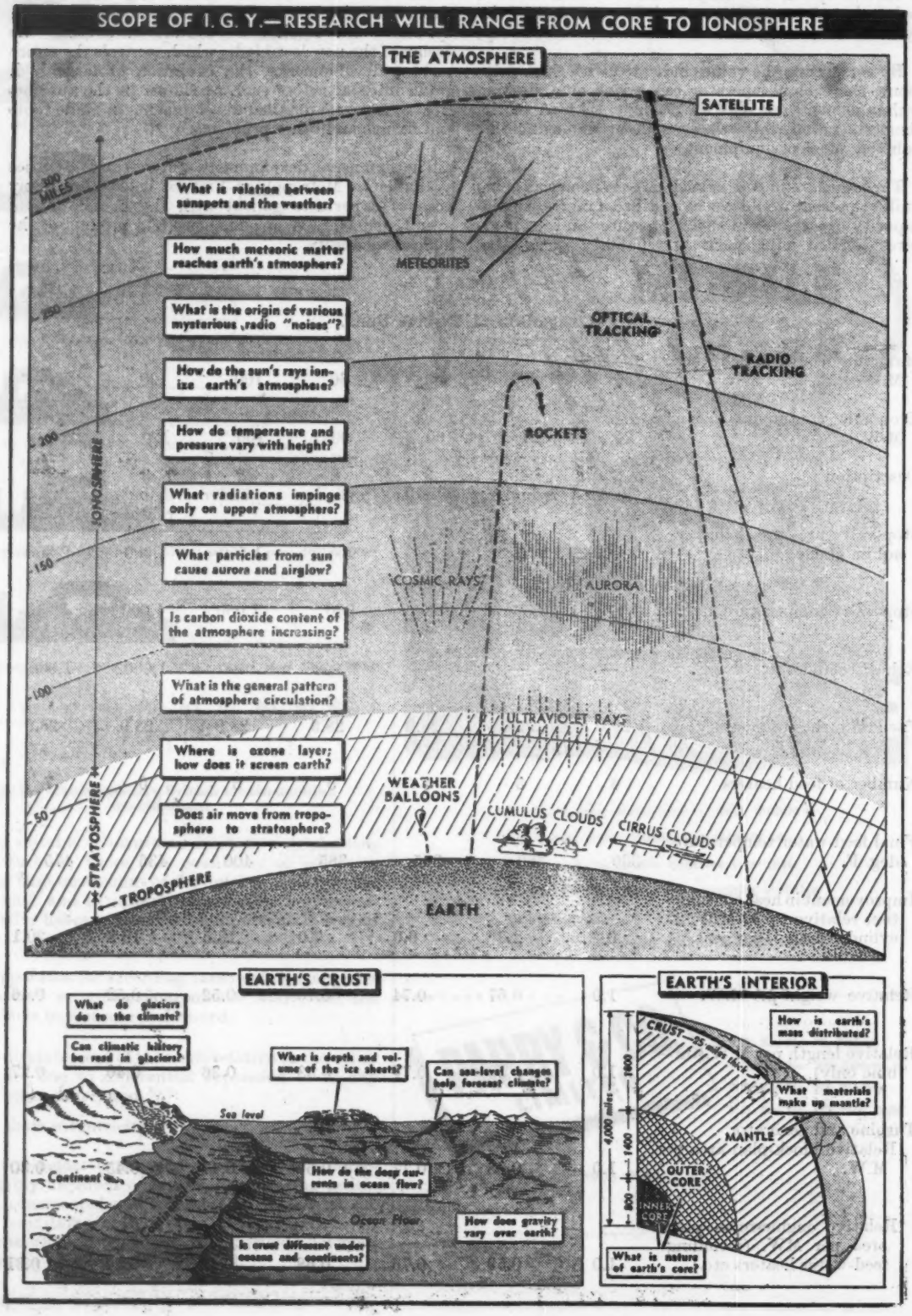
Turbo-generator sets of such large capacity as being built at present would not be justified if increase in the capacity or advance in steam pressures and temperatures implied impairment of reliability or relative increase in maintenance costs. Maximum reliablility is an absolute criterion demanding unremitting study of all the details of design. It includes the aerodynamic and mechanical studies underlying the design of the new last blade, which controls the entire turbine developments, the evolution of large high grade integral rotors such as shown in the turbine, *Fig.* 3, new and detailed developments in blade roots and fixings and other problems.

The extensive development and research facilities available to Metropolitan-Vickers backed by many yeas of experience gained with the installation of over 15,000,000 kW of plant, ensure a product of the highest reliability.

TABLE 1.

Comparison of Turbine Units.

Maximum continuous rating, M.W.	30	30	60	60	100	120	200
Economic continuous rating M.W.	24	24	60	60	100	120	200
Description	2 cylinder	1 cylinder	3 cylinder	2 cylinder	2 cylinder	3 cylinder reheat	3 cylinder reheat
Stop-valve pressure, 1 lb. per sq. in. gauge	600	900	900	900	1,500	1,500	2,350
Stop-valve temperature, deg. F.	850	900	900	900	1,050	1,000	1,050
Reheat temperature, deg.F.	—	—	—	—	—	1,000	1,000
Vacuum inches of mercury	29.0	29.0	28.9	28.9	28.9	28.9	28.9
Number of feed heaters	4	5	5	5	6	6	7
Final feed-water temperature, deg. F.	330	380	385	385	400	436	475
Improvement in heat consumption relative to 30-M.W. 2-cylinder design, per cent.	0	2.3	6.0	7.0	13.5	16.8	20.1
Relative weight per M.W.	1.0	0.67	0.74	0.70	0.52	0.52	0.46
Relative length per M.W.(turbine only)	1.0	0.58	0.74	0.53	0.36	0.40	0.27
Turbine and generator. Relative block-plan area per M.W.	1.0	0.68	0.77	0.67	0.47	0.45	0.30
Relative engine-room plan area per MW. (including feed-water heaters etc.)	1.0	0.59	0.76	0.68	0.47	0.44	0.31


SCOPE OF I. G. Y.—RESEARCH WILL RANGE FROM CORE TO IONOSPHERE
THE ATMOSPHERE
SATELLITE
300 MILES
250
200
150
100
50
0
IONOSPHERE
STRATOSPHERE
TROPOSPHERE
What is relation between sunspots and the weather?
How much meteoric matter reaches earth's atmosphere?
What is the origin of various mysterious „radio "noises"?
How do the sun's rays ionize earth's atmosphere?
How do temperature and pressure vary with height?
What radiations impinge only on upper atmosphere?
What particles from sun cause aurora and airglow?
Is carbon dioxide content of the atmosphere increasing?
What is the general pattern of atmosphere circulation?
Where is ozone layer; how does it screen earth?
Does air move from troposphere to stratosphere?
METEORITES
OPTICAL TRACKING
RADIO TRACKING
ROCKETS
COSMIC RAYS
AURORA
ULTRAVIOLET RAYS
WEATHER BALLOONS
CUMULUS CLOUDS
CIRRUS CLOUDS
EARTH
EARTH'S CRUST
What do glaciers do to the climate?
Can climatic history be read in glaciers?
What is depth and volume of the ice sheets?
Can sea-level changes help forecast climate?
Sea level
Continent
How do the deep currents in ocean flow?
Ocean Floor
How does gravity vary over earth?
Is crust diffeasnt under oceans and continents?
EARTH'S INTERIOR
How is earth's mass distributed?
CRUST—25 miles thick
What materials make up mantle?
4,000 miles
1800
1600
800
MANTLE
OUTER CORE
INNER CORE
What is nature of earth's core?

This Spinning Globe

Man exists on the thin crust of a spinning globe and, for all his investigations, has not been able in thousands of years to learn much about what goes on more than a few miles up and a few miles down. Man's known environment, as Lloyd V. Berkner has said, "is a veneer sanwiched on the upper side by the insulating atmosphere and the space beyond, and on the lower side by the unplumbed depths of the earth's interior. Yet the environment within this veneer is controlled almost completely by circumstances arising outside of it."

In an attempt to learn more about these circumstances scientists the world over began their greatest team effort at midnight on June, 30 Greenwich Mean Time. From mountaintops and submarine depths and from observatories that dot the map of the world they will observe and measure and record, as never before, the phenomena that shape the world. Fleets of ships, large expeditions and lonely outposts will be involved in the effort. Rockets will be pushed high into the upper air, and the first man-made moon will circle the earth in search of information.

The vast effort, known as the International Geophysical Year, or I.G.Y., will continue until the end of 1958. The eleven-year Sunspot cycle is about at its maximum. Scientists want an eighteen-month "year" to embrace this time of violent magnetic storms, as well as a more normal period for comparison.

The I.G.Y will thus probe into many problems covering many fields of knowledge where due to inadequate data it has not been possible to have a full view of nature. Some of these problems may be stated as follows :

Meteorology : What is the effect of that great refrigerator, the Antarctic continent, on the world's weather patterns ? To what extent do weather conditions in the southern hemisphere affect those north of the equator, and vice versa ? Are cold spells in one area balanced by dry spells in another, or do changes in the input of heat from the Sun account for such phenomena ? Is the increasing discharge of carbon dioxide into the atmosphere by industrial chimneys and automotive exhaust pipes making the earth warmer ?

Oceanography : To what extent do the frigid currents which creep through submarine canyons several miles below the ocean surface affect our climate ? How quickly does this water return to the surface ? Are the patterns of its movement changing ? What explains the strange, rhythmic changes in sea level which have been observed in many places, independent of ordinary tides ? To what extent does heat from the heart of the earth radiate into the oceans ?

Glaciology : How much ice is there in the world and is it expanding or contracting ? What can it tell us of past climates, or of future changes ? Why are glaciers in some parts of the world retreating while others are expanding ?

Solar Activity : What happens on the Sun to create the turmoil in the earth's atmosphere that follows a solar flare ? What causes the burst of cosmic rays and radio noise that may accompany their brief eruptions of light in the chromosphere—the atmosphere of the Sun ?

Ionospherics : What are the characteristics of the vast region of ionized gases, known as the ionosphere, which girdles the earth at elevations between 50 and 300 miles ? What sort of reactions take place there as cosmic rays and Sun particles penetrate that region ? What is the nature of the winds that seem to carry clouds of ions through various layers of this region ?

Aurora : What causes these curtains of light to hang in the polar skies ? Why do they expand so dramatically when the Sun acts up ? What is the composition of the aurora ? Do its displays throb simultaneously in the Arctic and Antarctic ? What point is the focus of their activity in each polar region ?

Geomagnetism : What is the shape of the earth's magnetic field in the space surrounding it? Why does its magnetism pulsate in various rhythms ?

Cosmic Rays : What is the origin of these particles, whose energies far exceed those of any yet generated on earth ? What is the mechanism which has produced them ? Why do they seem to reach the atmosphere evenly from all directions as though they came from everywhere in space ?

Gravimetry : Why does the speed of falling objects vary from day to day ? Why do plumb lines hang "straight down" in different directions as time passes ? What are the locations of key points on the earth in the third dimension, that is, how far are they from the centre of the earth ? What is the true shape of the earth and to what extent is the density of its crustal layers uneven ?

Geodesy : What are the precise locations of the various continents and isolated islands ? Is there any indication that they are imperceptibly in motion with respect to one another ? Is there evidence of the former continental drift ?

Seismology : What are the contours of underlayers in the earth's crust, as revealed by seismic explosions ? Which ocean floors are purely oceanic in nature and which seem to have once been continental ? What is the relationship between weather phenomena—typhoons and other storms—and microseisms (miniature earth tremors) ?

What benefits will the I.G.Y. bring to mankind ? Fundamentally, the goal of the I.G.Y. is to obtain basic knowledge. The data to be obtained through observations of weather, cosmic rays, the ionosphere and aurora will be so voluminous that no man could fathom their meaning unaided. Computing and classifying machines are to be used for the analysis. When

(*Continued on page* 30)

Book Review

CAVITATION IN HYDRODYNAMICS: Proceedings of a Symposiun held at the National Physical Laboratory, Sept. 14-17, 1955, H.M.S.O., London, 1956, 30sh/-, 500 pages.

The publication forms the deliberations of an imposing symposium on cavitation in hydrodynamics presented mainly from workers in Britian and the United States, with welcome contributions from Japan, Russia, Switzerland, Austria and Denmark. The subject was divided into six major sections covering a general review in the opening address by P. Eisenberg of the Office of Naval Research of the United States; Factors govering cavitation inception; Experimental techniques; Scale effect factors; Effects on hydrodynamic performance; and Cavitation damage. An informal discussion on ultrasonic cavitation and a list of participants is included in the appendix.

To the hydrodynamicist and the hydraulic engineer, the problem of cavitation is of importance in the design of cavitation-free equipment and in determining the scaling laws for cavitation-model testing. For many years it was assumed that cavitation in a hydraulic flow occured when the local pressure dropped to vapour pressure. However, it has now been realised that cavitation inception pressure does not have a fixed value, since under certain circumstances, especially those existing in water tunnels, inception may require some negative pressure or tension. The various papers present these aspects and throw valuable light on these problems associated with the inception, growth, decay and collapse of cavities in a rapid periodic sequence. Unfortunately many papers are of a highly mathematical nature and may appear to the practising engineer of having little direct value, although it cannot be doubted that the fundamentals and the causes of cavitation are now fully established. There are a remarkable series of photographs on the cavitation caused on a destroyer's propeller bringing home the urgent need of model experiments on mixed flow. The set of papers dealing with two dimensional flow on foils and struts and the determination of the forces and the requirements for shape from low speeds upto cavitation conditions, provide clear guidance to the turbine and propeller designers.

Among the various testing techniques available for the solution of cavitation problems, described in the various papers, are water tunnels, high speed photography, powerful stroboscopic illumination, electronics, acoustics, and magnetostriction. The life history of bubbles is vividly brought to light in the very fast rate photographs taken at the rate of a million per second, which by direct observation appeared no more than a blurred mass. One of the most lucidly written papers on the experimental study of cavitation erosion intensity is contributed in the Russian paper covering details of the effects of cavitation on hydraulic structures.

The assemblage of really authoritative matter on several aspects of caviation render this symposium proceedings a unique work of reference for all interested in this complex phenomena.

S. K. GHASWALA.

Switchgear Principles by P.H.G. Crane, published by Cleaver-Hume Press Ltd., 31, Wright's Lane, Kensington, London W.B., p.p.238 price 25 sh.

The modern electrical power system is notable for its compexity and for the very high fault powers involved when failure occurs. Power switchgear has thus been subjected to considerable development over the last fifty years or so, and a large amount of more or less specialized literature on this subject has appeared during this period. The elementary student's needs, however, have been somewhat neglected in-in so far as his general knowledge of switchgear must usually be gained by reference to appropriate sections of different works on electrical engineering.

The present volume is therefore an attempt to ease this situation

The chapters of the book cover : The Supply and Control of Electricity, Short Circuits and Overvoltages, Protection and Switchgear, Electrical Discharges, Principles of Circuit-Breaking, Oil Circuit-Breakers, Air Circuit-Breakers, Switchgear Components, Switchgear Accommodation, Tests and Specifications.

The book can be confidently recommended for the use of the students in electrical engineering.

Proceedings of the Rubber in Engineering Conference, London, September 26, 1956. published by the Natural Rubber Development Board, Market Buildings, Mark Lane, London E.C.3.

This is a very timely publication when the use of rubber is extensively widening its range and variety. There are five Papers each followed by discussion by best experts in each field. The one on "The Use of Rubber in Heavy Engineering" by S.W March would interest our readers very much.

(*Continued from page* 29)

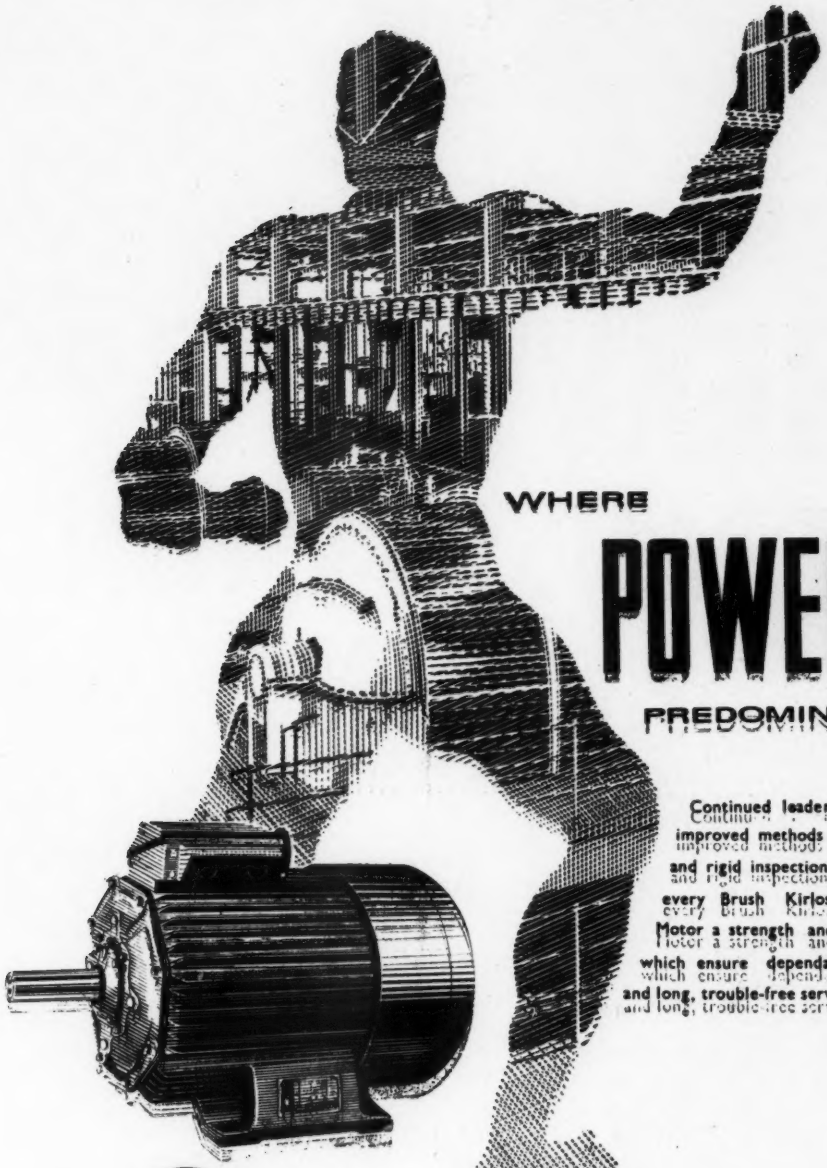
Editorial

this is done some of the basic truths concerning our planet, its atmosphere and the space through which it is flying may come to light.

Three centuries ago Sir Isaac Newton demonstrated that gravity holds together the solar system according to a series of mathematical laws. Albert Einstein revised and extended Newton's laws and sought to relate the two great physical forces : gravity and magnetism. Nevertheless for every question answered a dozen new questions have arisen. The information collected during the I.G.Y. may enable some future genius to carry this system of laws another great step forward.

It may eventually be possible to see the elephant as a whole but this might not be achieved for a decade or more. Dr Joseph Kaplan said that "these large views which are characteristic of astronomy and geophysics have given the I.G.Y. a role which may far transcend the gathering of data and the observing of physical processes."

These broader aspects of the I.G.Y. he added, may prove to be as important as the scientific achievements themselves.



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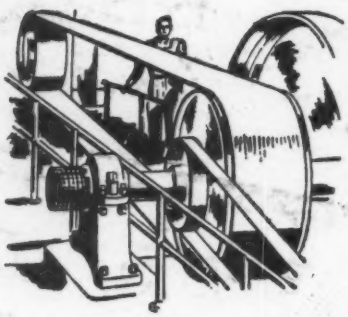
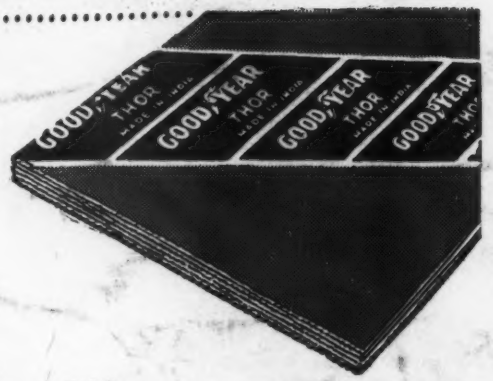
THOR HEAVY DUTY TRANSMISSION BELTING





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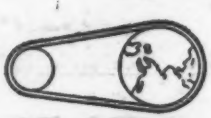

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